EXHIBIT 10

Last Updated November 9, 2007

HDL™-64E

RESOURCE MANUAL

Laser Safety Parameters

High Definition Lidar™ Sensor

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INTRODUCTION

The scope of this report is to submit this report to the Food and Drug Administration for laser array approval. This Product consists of a 64-piece laser array that is mountable on top of a vehicle. The array revolves around an axis sending out laser beams to collect terrain data. This terrain data is used for obstacle detection during a vehicle excursion.

FOREWORD

In recent years, LASER (Light Amplification by Stimulated Emission of Radiation) devices have become less expensive and more commonplace. Lasers are used in supermarket scanners, CD and DVD players, construction and surveying instruments, laser pointers for presentations, and for other medical and industrial purposes. Also, lasers are often used outdoors as part of orchestrated laser light shows at theme parks, casinos, and special events. Lasers have become a ubiquitous part of consumer electronics.

In the United States, laser safety is dealt with by regulations, which are part of federal law.

How Lasers are Classified:
The level of a laser hazards in a product is defined by the Class the laser falls in.

Class I is non-hazardous and Class IV is the most hazardous. There are two classifications to consider:

- the Class of the product (how much laser radiation is accessible to the user) and
- the Class of the radiation (how much laser radiation is accessible to service personnel).

The Class of the product is based upon the amount of laser radiation accessible to the user during normal operation of the product. Although a product may be classified as Class I, the product may incorporate a Class I, IIa, II, IIIa, IIIb or Class IV laser diode internally. This is the laser radiation accessible to service personnel during a service function.

For example, a laser product such as a copy machine could have Class I laser radiation accessible to the user. Inside the product there could be Class IV laser radiation accessible to service personnel.

The principal concern for people is the possibility of being illuminated with a laser duringnormal operations. Exposure to relatively bright light such as a laser, when the eye is adapted to low-light levels, can result in temporary visual impairment. Visual effects can last from several seconds to several minutes.

The Food and Drug Administration (FDA) has authority to regulate light-emitting products and electronic product radiation. The FDA regulates lasers under their "Performance Standards for Light-Emitting Products". This FDA standard utilizes the American National Standard Institute (ANSI Z136.1) recommended Maximum Permissible Exposure (MPE), to prevent ocular tissue damage in allapplications. The MPE is used to calculate the Nominal Ocular Hazard Distance (NOHD), which is the distance of a laser beam beyond which an individual may be exposed without risk of ocular tissue damage.

Every product using lasers has to be designed to ensure that it operates in accordance with best practice with regard to the safety of lasers, LEDs and other optical hazards in order to minimize the risk of personal injury to staff or third parties.

In order to do this, one written report, as comprehensive as possible, is submitted to FDA for final evaluation. FDA will make it sure that it is following the correct procedures and taking the necessary precautions as laid down by the various standards.

FDA will test and certify the prototype or completed product to the appropriate standard or standards and provide a full test report including details of:

- Measurement test results
- Accessible emission limits
- Required engineering controls
- Required labeling
- Required information in user's manual and product brochures
- Failure modes of drive electronics and other reasonably foreseeable failures affecting safety

In the United States, compliance with the regulations for lasers and laser products issued by the Center for Devices and Radiological Health (CDRH) of the Food and Drug Administration (FDA) is mandatory. The current CDRH regulations pertaining to laser emissions are found in 21 CFR 1040.10 and 1040.11. CDRH, which is part of FDA, has the task of enforcing the regulations. The laser product regulation is known as 21 CFR 1040.10 . This document represents the full completion of 21 CFR 1040.10 and 1040.11, and the calculations performed in this document were based on IEC standard 60285-1.

Obstacle Detection and Avoidance Systems are very effective electronic navigation systems. There are different working principles and among these are LASER based systems that are used by the described prototype.

This system consists of a 64 infrared lasers mounted on top of a vehicle. The system revolves around an axis sending out laser beams to collect terrain data. This terrain data is used for obstacle detection during a vehicle excursion.

IR laser diodes are pulsed diodes and the stated power rating is peak. While they have "high" peak power ratings, the average power ratings are typically less than 1mW as they must run at a very low duty cycle. They are suitable for rangefinder or similar applications. These laser diodes come in plastic packages that look much like LEDs and, since there is limited opportunity for cooling the devices and overheating is a concern, power dissipation is one of the major limiting factors. This has an important side benefit of making the product safe by guaranteeing continuous low power.

The Detection System described in the following report is using pulsed laser diodes activated with a very low duty cycle, making the entire system a safety class I product. The following Product Report contains construction and performance details describing how the Laser Obstacle Detection and Avoidance System fully complies with the FDA safety regulations.

LASER PRODUCT REPORT

PART 1: MANUFACTURER AND REPORT IDENTIFICATION

1.1 Manufacturer:
Manufacturing Firm **Velodyne Acoustics**
Address **345 Digital Drive, Morgan Hill, CA 95037**

Corresponding official: **David Hall**

Signature ____

Name & title **Chief Executive Officer**

Telephone number **408-465-2821**

Firm's Prime Contact or Responsible Person if different from above: **Bruce Hall**

Name & title __________**President, Velodyne Acoustics Inc**______________________

Telephone number _________**408-465-2800**______________________________

1.2 Importing agent (For manufacturers exporting to the U.S., see 21 CFR 1005.25.):
Signature **N/A**
(Or attach copy of written agreement with agent)
Name & title **N/A**
Address **N/A**

Telephone number **N/A**

1.3 Report type:
(**X**) Laser Product Report, or
(   ) Supplement to CDRH Accession No. ________ submitted on (date) ___________________________

1.4 Date of this report: **04/26/07**

PART 2: PRODUCT AND MODEL IDENTIFICATION

2.1 List all names, brand names, model numbers and model family designations of the laser product being reported. If the product is sold by other companies under different brand names, also give the names and addresses of the companies, the brand names, and the model numbers, and indicate how the brand names and model numbers correspond with your own brand names and model numbers.

Product Name: HDL-64E

2.2 Is your laser product the result of the modification of a laser product certified by another manufacturer? [see 1040.10(i)]
(   )Yes
(**X**)No
If yes, identify the manufacturer(s), brand(s), and model number(s).

NOTE: Modification involves any changes to the product that affect its classification, performance or labeling requirements (as required by the standard or an approved variance).

2.3 Does your laser product incorporate an unmodified, certified laser product?
(   )Yes
(**X**)No
If yes, identify the manufacturer(s), brand(s), and model number(s).

2.4 Does your product incorporate a noncertified laser product?
(   )Yes
(**X**)No
If yes, identify the manufacturer(s), brand(s), model(s), and describe the type of product.

2.5 Does your laser product incorporate a removable laser system or systems as defined in 1040.10(c)(2)?
(   )Yes
(**X**)No
If yes, identify the manufacturer(s), brand(s), and model number(s).

2.6 If the laser product, as introduced into commerce, is not supplied with a laser or laser system or the product does not incorporate a laser or laser system, report by manufacturer and model number which laser or laser system, if any, is recommended by you for use with the product.

N/A

2.7 If you do not recommend a specific laser or laser system for use with the reported product, state the specifications of the laser or laser system to be incorporated.

N/A

PART 3: COMPLIANCE WITH THE LABELING REQUIREMENTS

For each of the following labels required for the product being reported, provide a sample or a facsimile of each label. Clearly indicate the locations on the product of all required labels in your response to this Part or to Part 5. Reference to diagrams, photographs, blueprints, product literature, etc., is acceptable. See Compliance Guide, page 7, for assistance.

3.1 Certification label - Required on all laser products (1010.2).
Is the label (or a copy) submitted with this report?
(**X**)Yes
(   ) No
Location on product: **__On laser housing. See Figure 1.**

FIGURE 1

3.2 Identification label - Required on all laser products (1010.3).
Is the label (or a copy) submitted with this report?
(**X**)Yes
(   )No
Location on product: **__On laser housing__________________________**

See Figure 2.

FIGURE.2

3.3 Warning logotype - Required on Class II, III, and IV laser products. [1040.10(g)(1),(2),(3),(4),(8),(9),(10)].
Is the label (or a copy) submitted with this report?
(   )Yes
(**X**)No
Location on product: **N/A**

3.4 Warning label - Required on Class IIa laser products [1040.10(g)(1)(i)]. Is the label (or a copy) submitted with this report?
( )Yes
(**X**)No
Location on product: **N/A**

3.5 Aperture label(s) - Required on Class II, III and IV laser products [1040.10(g)(5),(8),(9),(10) or 1040.11(a)(3)].
Are the label(s) (or copies) submitted with this report?
( )Yes
(X)No
Location on product: **N/A**

3.6 Label(s) for noninterlocked protective housings [1040.10(g)(6),(8),(9),(10)]. Are the label(s) (or copies) submitted with this report?
( )Yes
(**X**)No
Location on product: ______________________________

Are the label(s) visible both prior to and during opening or removal of housing?
( )Yes
(**X**)No **N/A**

3.7 Label(s) for defeatably interlocked protective housings [1040.10(g)(7),(8),(9),(10)].
Are the label(s) (or copies) submitted with this report?
( )Yes
(**X**)No **N/A**
Location on product: _ **This laser product contains non-defeatable interlocks__**

Are the label(s) visible both prior to and during interlock defeat?
( )Yes
(**X**)No **N/A**

3.8 Label(s) for optionally interlocked protective housings. (See Laser Notice of March 2, 1977, dealing with optional interlocks.) Is the label (or a copy) submitted with this report?
( )Yes
(**X**)No
Location on product: __**N/A**______________________________

Are labels visible both prior to and during opening or removal of the housing?
( )Yes
(**X**)No

NOTE: If the labeling requirements are inappropriate to your product, you may apply for approval of alternate labeling. See sections 1010.2, 1010.3, and 1040,10(g)(10).

PART 4: COMPLIANCE WITH THE INFORMATIONAL REQUIREMENTS

4.1 Submit copies of user and servicing information (operator and service manuals) for your laser product. If the manuals are very extensive, submit those portions that confirm compliance with Section 1040.10(h) [and 1040.11(a)(2), if a medical laser product] and that permit understanding how your laser product functions. See Compliance Guide, page 8, for assistance. Are copies of user and service information attached to this report?
(   )Yes
(X)No
If "Yes," please identify attachment: __________
If "No," please explain why not

A User's Manual is attached as Appendix A

NOTE: These materials may also be used in the product description required by Part 5.

4.2 Submit copies of any catalogs, specification sheets, and descriptive brochures for Class IIa, II, III, and IV laser products.
Are copies of catalogs, specification sheets, or brochures attached to this report?
(   )Yes
(X)No
If "Yes," please identify attachment:__________
If "No," please explain why not

This Product is a Class 1M device.

PART 5: DESCRIPTION OF THE PRODUCT

5.1 Describe the product and its function. You may refer to brochures and manuals submitted with this report. Please include drawings or photographs adequate to document compliance of the product with the performance and labeling requirements.
Is a product description attached to this report?
[**X**]Yes
[ ]No
Please identify attachment: ____________________

The product consists of 64-piece laser array that is mountable on top of a vehicle. The array revolves around an axis sending out laser beams to collect terrain data. This terrain data is used for obstacle detection.

The product is comprised of 4 Laser Assemblies consisting of 16 Lasers each (totaling 64 lasers). Two Laser Assemblies are located in the upper plane (which are referred to as Upper Left Head and Upper Right Head) and two Laser Assemblies located in a lower plane (referred to as Lower Left Head and Lower Right Head). The Lower Heads are oriented so that aimed at the ground near the product. The Upper Heads are oriented so that these laser pulses are substantially directed also towards the ground, but to a further distance than the Lower Heads.

Initially, two lasers in each of the upper heads are pulsed (for example Lasers 1 and 2). The optical pulse duration is approximately 5 nanoseconds. Four microseconds later (250 kHz burst frequency), two other lasers (Lasers 3 and 4) in each of the upper head are pulsed. Four microseconds later, two other lasers (Lasers 5 and 6) are triggered. This process repeats until all 16 lasers have been pulsed. The overall period for this sequencing of the laser pulses is 32 microseconds. This process of sequentially pulsing the 16 lasers in each of the upper heads repeats two additional times (for a total of three cycles).

After these three cycles in the upper head, a single sequencing cycle is conducted for the Lower Heads. At the completion of this cycle, the loop repeats (3 Upper Head Cycles then 1 Lower Head cycle).

While transmitting laser pulses, the product will rotate at a rate of approximately 600 revolutions per minute (10 revolutions per second).

5.2 Describe the external and internal laser radiation fields and paths. Beam path diagrams indicating protective housing, beam attenuators, viewports, scanners, targets, etc. would be helpful. Please identify external and internal laser power or energy levels where applicable.
Are description and diagrams of the laser radiation fields and paths attached?
[**X**]Yes
[ ]No
Please identify attachment: ___**See Figure 3**

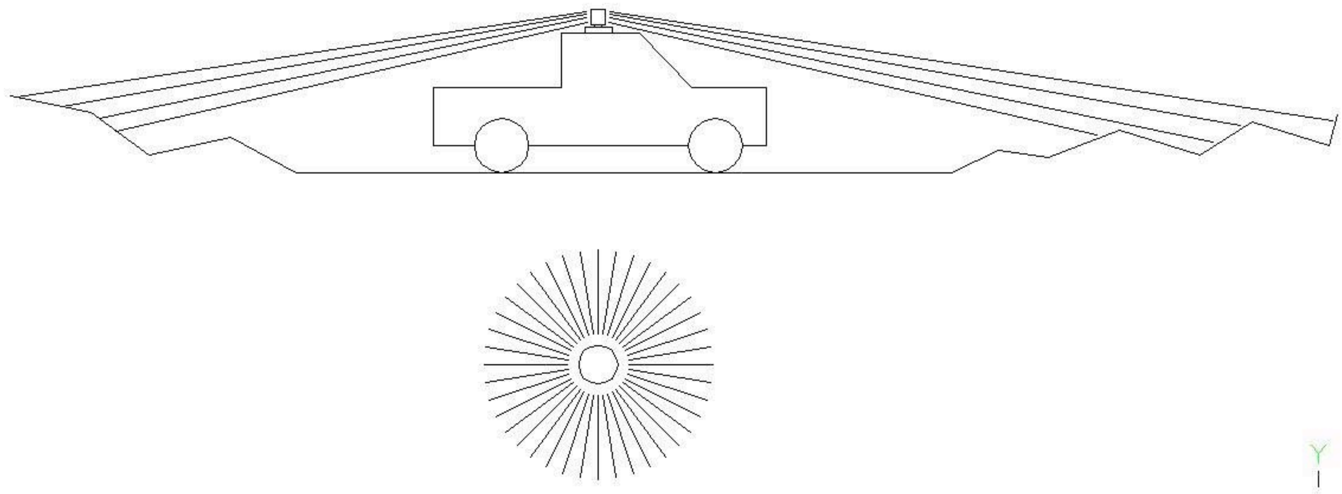


FIGURE 3
DEPICTION OF THE PRODUCT LASER EMISSION

5.3 List the procedures performed during **operation** and indicate those collateral and laser radiation fields specified in Part 6 to which human access is possible when those procedures are being performed. [See definition of human access - Section 1040.10(b)(15)].
Operational procedures and accessible radiation:

When power is applied to the HDL-64E, the Product will begin to rotate. Once a minimum rotational speed is achieved, the Lasers will be allowed to transmit. This rotation speed is monitored by an accelerometer and comparator circuit. The typical minimum speed of rotation before the lasers begin to transmit is 300 revolutions per minute.

The peak power emitted by each laser is controlled using a DSP controlled pulse charging circuit. In addition, the power supplies used to provide this pulse charge are limited in the amount of charge they can provide in the system. So, typically, the Product can only operate the lasers at approximately half of their rated maximum power (45 watts). To provide margin in the safety calculations, this number has been raised to two-thirds of the rated maximum power (60 watts)

Laser radiation is only possible when the Product is rotating at the above mentioned minimum rate. When radiating, the Laser emissions only occur through the Product's output window.

5.4 List the procedures performed during **maintenance** and indicate those collateral and laser radiation fields specified in Part 6 to which human access is possible when those procedures are being performed. See the definition of maintenance in section 1040.10(b)(24) and Compliance Guide, page 5.
Maintenance procedures and accessible radiation:

No maintenance allowed by the user on this product.

5.5 List the procedures performed during **service** and indicate those collateral and laser radiation fields specified in Part 6 to which human access is possible when those procedures are being performed.
Service procedures and accessible radiation:

No service allowed by the user on this product.

PART 6: LEVELS OF ACCESSIBLE LASER RADIATION AND CLASSIFICATION OF THE LASER PRODUCT

6.1 Give the specifications of all laser radiation fields described in Part 5 to which human access is possible during **operation**. See Section 1040.10(e) for measurement parameters. Indicate whether the values are measured or based on calculations. Whether measured or calculated, please provide a diagram of your measurement/calculation set-up, and pertinent dimensions such as separation distances, source and detector aperture size, etc. in order to show how your measurements or calculations are in accordance with 1040.10(e).

Please provide as much of the following as is appropriate to your product:
wavelength(s): **905** nm
maximum average radiant power: **Get from Table 1 Below**
beam divergence: **3.5 mrad horizontally**
0.5 mrad vertically
Using the 30 to 100 foot data from Table 1

The beam spot size varies with distance from the Product. Table 1 shows the beam spot size and area versus distance FORM THE Product's output window.

Distance	Beam Width(mm)	Beam Height(mm)	Beam Area (mm^2)
14 mm	16.0	45.0	720.0
100 mm	17.0	43.0	731.0
1 foot	16.1	31.5	507.2
5 feet	14.5	14.6	211.7
10 feet	12.9	10.8	139.3
16 feet	15.4	8.5	130.9
20 feet	16.0	7.8	124.8
25 feet	20.6	9.3	191.6
30 feet	25.2	9.7	244.4
100 feet	101.6	20.3	2062.5

TABLE 1
LASER SPOT SIZE vs DISTANCE

Pulsed Operation Characteristics:

peak power: **60 W, maximum**

pulse durations: **5 nanoseconds**

pulse energy: **60 watt x 5 nanoseconds = 300 nJ per laser**

repetition rate: **31.25 khz / 32μs**

burst rate: **250 kHz / 4 us**

if applicable:

Not Applicable

maximum irradiance or radiant exposure: __**N/A**___ W or J cm-2
max. radiance or integrated radiance: ___**N/A**__ W or J cm-2 sr-1

Are measurement parameters, diagrams, calculations, and/or specifications submitted as an attachment to this report?
(**X**)Yes - Please identify attachment: ___**See Below**_____
(   )No

Table 1 (above) details the beam spot size versus distance.

Calculations for energy and power levels transmitted by the Product are conducted in this section.

Calculations for the Accessible Emission Limit are based on IEC 60285-1 and are also attached in this section.

It should be noted that is this document, since the upper heads transmit 3 times more often than the lower head (so 3 times the energy will be transmitted from the upper head than the lower head), the calculations in this document will conducted for only the upper head.

The analysis is also broken into four different distances from the laser sources. IEC 60825-1 specifies that the laser power measurement be made 100 mm from the laser source using a 7 mm aperture (for Class 1M). We also conduct the safety calculations 100 mm from the output window, 1 foot from the output lens, and 20 feet from the output lens, which is approximately the minimum laser spot size.

IEC 60285-1 dictates that the output power (or energy) be measured 100 mm from the source, which in this product's case is an array of laser diodes. The upper head is located approximately 86 mm from the output window of the product. Therefore, the first laser beam spot size will be check approximately 14 mm for the output window.

Case a) 14 mm from the upper output window the beam dimension is 45 x 16 mm = 720 mm^2

Note: Two lasers may be fired simultaneously in this case, and both lasers overlap the stated beam dimension, so the power calculations will be doubled for this case.

Case b) At 100 mm from the upper output window, the beam dimension is 43 x 17 mm = 731 mm^2

Note: Two lasers may be fired simultaneously in this case, and both lasers overlap the stated beam dimension, so the power calculations will be doubled for this case.

Case c) At 12 inches (304.8mm) from output lens, the dimension is 31x14.5mm = 507.2 mm^2

Case d) At 20 feet (6096 mm) from the output lens, the beam diameter is 8x16mm = 124.8mm2

Case d is the minimum spot size outside the lens.

Per IEC 60285-1, a receiver with 7mm diameter shall be used to measure the output power form the Product. This 7 mm diameter detector will have a surface of 38.465mm^2

Since the area of the detector is smaller than the laser spot sizes, a Detector Correction Factor for this aperture will be used. This Detector Correction Factor is:

Case a) 38.465 / 720 = 0.0534
Case b) 38.465 / 731 = 0.0526
Case c) 38.465 / 507.2 = 0.0758
Case d) 38.465 / 124.8 = 0.3082

Per IEC 60285, for a repetitively pulsed laser source, three conditions must be checked to validate the Product Laser Classification. The Product shall be Classified as the worst case rating of these three conditions.

Condition 1: Single Pulse Accessible Emission Limit

The formula for calculating the detected single pulse energy is:

[Peak Power] * [Pulse Width] * [Number of Lasers Overlapping] * [Detector Correction Factor]

Case a: Detected Laser Energy$_{SP}$ = 60 [W] * 5 [ns] * 2 * .0534 = 32.0 nJ
Case b: Detected Laser Energy$_{SP}$ = 60 [W] * 5 [ns] * 2 * .0526 = 31.6 nJ
Case c: Detected Laser Energy$_{SP}$ = 60 [W] * 5 [ns] * 1 * .0758 = 22.7 nJ
Case d: Detected Laser Energy$_{SP}$ = 60 [W] * 5 [ns] * 1 * .3082 = 92.5 nJ

The single pulse AEL is calculated from Table 4 of IEC 60285-1,

Class 1M AEL$_{SP}$ = 2 * 10^{-7} * C_4

Where C_4 is derived from Table 10:

$C_4 = 10^{0.002*(\_- 700)}$

Where _ = 905 [nm]

C_4 = 2.57

Class 1M AEL$_{SP}$ = 514 nJ

Condition 1 Conclusion

Since all Cases are lower than the Class 1M AEL$_{SP}$, the Product is rated as Class 1M for this Condition.

Condition 2: Average Accessible Emission Limit (1 second exposure)

The average power is calculated similarly to Condition 1, except more lasers overlap in the Pulse Repetition period. The formula for calculating the fixed position power is:

[Detected Laser Energy$_{SP}$] * [Pulse Repetition Rate] * [Laser Overlap] * [Head Overlap] * [Sequential Duty Cycle] * [Rotation Factor]

where the Laser Overlap is the number of times within the Base Repetition Period a laser emission illuminates the detector. In Cases a and b, there are 8 separate laser emissions that overlap the same spot size (all lasers within the burst period overlap). In Case c, this number is 3 to account for the maximum overlap within the head as the unit rotates. In Case d, there is no overlap, so this number is 1.

the Head Overlap is the number of Heads that will cross the fixed position detector in a single rotation. In Cases a, b and c, this number is 2. In Case d, there is no overlap of left and right heads, so this number is 1.

the Sequential Duty Cycle is how often the Upper Head of the Product is triggered in the system operation. This number is 0.75.

and the Rotation Factor is the ratio of laser spot size to the circumference at the given distance form the output window.

Rotation Factor = [Spot Width] / [Circumference of Detector Distance of Center of Rotation]

The Rotation Factors are:

Case a: 16 [mm] / { 2 * * (86 + 14 [mm] } = .0255
Case b: 17 [mm] / { 2 * * (86 + 100 [mm] } = .0145
Case c: 16.1 [mm] / { 2 * * (86 + 304.8 [mm] } = .0066
Case d: 16 [mm] / { 2 * * (86 + 6096 [mm] } = .0004

Case a: Det Laser Power$_{av,rot}$ = 32.0 [nJ] * 31.25 [kHz] * 8 * 2 * .75 * .0255 = 0.31 mW
Case b: Det Laser Power$_{av,rot}$ = 31.6 [nJ] * 31.25 [kHz] * 8 * 2 * .75 * .0145 = 0.17 mW
Case c: Det Laser Power$_{av,rot}$ = 22.7 [nJ] * 31.25 [kHz] * 3 * 2 * .75 * .0066 = 0.021 mW
Case d: Det Laser Power$_{av,rot}$ = 92.5 [nJ] * 31.25 [kHz] * 1 * 1 * .75 * .0004 = 0.0009 mW

The Class 1M average power AEL is calculated from Table 4 (using 10 s emission duration),

Class 1M AEL$_{SP}$ = $3.9 * 10^{-4} * C_4 * C_7$

Where C_4 is derived in Condition 1 = 2.57

And C_7 is derived from Table 10 = 1

Class 1M AEL$_{av}$ = 1 mW

<u>Condition 2 Conclusion</u>

Since all Cases are lower than the Class 1M AEL$_{av}$, the Product is rated as Class 1M for this Condition.

<u>Condition 3: Repetitive Pulse Accessible Emission Limit (10 second exposure)</u>

The calculated emission from Condition 1 will be used to check for the Laser Classification for this Condition.

Case a: Detected Laser Energy$_{SP}$ = 32.1 nJ
Case b: Detected Laser Energy$_{SP}$ = 31.6 nJ
Case c: Detected Laser Energy$_{SP}$ = 22.7 nJ
Case d: Detected Laser Energy$_{SP}$ = 92.5 nJ

We must determine the number of laser emissions that will illuminate the detector over a period of 10 seconds to calculate to AEL$_{train,\ SP}$. This number shall be calculated using the following formula:

N = [Pulse Repetition Rate] * [Laser Overlap] * [Head Overlap] * [Sequential Duty Cycle] * [Rotation Factor] * [Illumination Duration]

$C_5 = N^{-0.25}$

However, if multiple optical pulses occur within an T_i (18us period as defined by Table 3), they are considered as a single pulse to determine N, and the energies of the individual pulses are added to compared to AEL of T_i . This is the case in Sub-Cases a, b and c. For these Cases the number is calculate using the following formula.

N = [Rotation Factor] * [Sequential Duty Cycle] * [Head Overlap] * [Illumination Duration] / [T_i]

$C_5 = N^{-0.25}$

Case a: C_5 = {.0255 * 0.75 * 2 * 10 [s] / 18 [us]}$^{-0.25}$ = .083
Case b: C_5 = {.0145 * 0.75 * 2 * 10 [s] / 18 [us]}$^{-0.25}$ = .095
Case c: C_5 = {.0059 * 0.75 * 2 * 10 [s] / 18 [us]}$^{-0.25}$ = .119
Case d: C_5 = {31.25 [kHz] * 1 * 1 * 0.75 *.0004 * 10[s]}$^{-0.25}$ = .321

The limits are then calculated by:

$AEL_{train,\ SP} = AEL_{SP} * C_5$ = 514 nJ
$AEL_{train,\ SP} = AEL_{18us} * C_5$

Class 1M AEL_{18us} = $7 * 10^{-4} * t^{0.75} * C_4$ (from IEC 60285-1 Table 4)
Where t = 18 us and C4 = 2.57
= 497 nJ

Class 1M

Case a: $AEL_{train,\ SP\ 1M}$ = 497 nJ * .083 = 41.3 nJ
Case b: $AEL_{train,\ SP\ 1M}$ = 497 nJ * .095 = 47.2 nJ
Case c: $AEL_{train,\ SP\ 1M}$ = 497 nJ * .119 = 59.1 nJ
Case d: $AEL_{train,\ SP\ 1M}$ = 514 nJ * .321 = 165.0 nJ

<u>Condition 3 Conclusion</u>

Since all Cases are lower than the Class 1M $AEL_{train,\ SP}$, the Product is rated as Class 1M for this Condition.

<u>Condition 3B: Repetitive Pulse Accessible Emission Limit (18 us exposure)</u>

Since there are multiple pulses within an 18 us period, we must also check that the total energy in the 18 us period does not exceed the AEL for 18us.

Also, since there is no overlap of multiple laser emissions, there is no burst mode operation in 18 us for Cases d, so this Case will not be evaluated in this calculation.

The maximum number of laser emissions that can occur in an 18 us period is:

Case a: 5
Case b: 5
Case c: 3

So, the total energy in this 18 us period is:

Sub-Case a: 5 * Detected Laser $Energy_{SP}$ = 5 * 32.1 nJ = 160.5 nJ
Sub-Case b: 5 * Detected Laser $Energy_{SP}$ = 5 * 31.6 nJ = 158.0 nJ
Sub-Case b: 5 * Detected Laser $Energy_{SP}$ = 3 * 22.7 nJ = 68.1 nJ

Class 1M AEL_{18us} = $7 * 10^{-4} * t^{0.75} * C_4$ (from IEC 60285-1 Table 4)
Where t = 18 us and C4 = 2.57
= 497 nJ

Condition 3B Results

Since all Cases are lower than the Class 1M AEL_{18us}, the Product is rated as Class 1M for this Condition.

6.1 CONCLUSION

Since the Product meets the Accessible Emission Limits for these three conditions. It is classified as a Class 1M Product.

6.2 Indicate the Class of the laser product, based on your response to Part 6.1.
(**X**) Class I ( ) Class IIa ( ) Class II
( ) Class IIIa ( ) Class IIIb ( ) Class IV

6.3 Give the specifications of all possible laser radiation fields described in Part 5 to which human access is possible during **maintenance**.

No user maintenance allowed or required.

Are specifications attached?
( )Yes
(**X**)No

6.4 Give the specifications of all possible laser radiation fields described in Part 5 to which human access is possible during **service**.

No user service allowed or required.

Are specifications attached?
( )Yes
(**X**)No

6.5 Describe all collateral radiation associated with the product. Report the source(s) and levels and describe where and under what circumstances such radiation is accessible.

This product does not have any collateral radiation. There is not any circumstance such that radiation is possible.

Is description attached? ( )Yes (**X**)No

6.6 EXTENDED NOMINAL OCCULAR HAZARD DISTANCE (ENOHD)

As this product is rated as a Class 1M product, it is not intended for use with any products which use viewing optics, such as binoculars. However, if an optic viewing device is used with this product, the following calculations will determine the distance at which the laser emission level falls below the Maximum Permissible Exposure (MPE) level. Note that this level is different than the Accessible Emission Limit (AEL) used in section 6.1. Also, because these calculations are associated with a viewing optic, the detector aperture is increased to 50mm (as opposed to 7 mm in the previous calculations).

In this calculation we will use the same distance information from section 6.1 (14mm, 100mm, 1 foot and 20 feet from the output window) plus the additional distances of 5 feet, 10 feet, 16 feet, 30 feet and 100 feet.

The calculation from section 6.1 will be repeated for these calculations, with the changes in aperture size and acceptance levels. Since the detector area is larger than the all laser spots (except for the laser spot at 100 feet), as shown in Table 1, the Detector Correction Factor in all cases is 1 (even for the 100 foot case). The case names have also been changed for better indication of the distance from the output window.

<u>Condition 1: Single Pulse Maximum Permissible Exposure Limit</u>

The formula for calculating the detected single pulse energy density is:

[Peak Power] * [Pulse Width] * [Number of Lasers Overlapping] * [Detector Corr Factor] / [Spot Area]

Case 4mm: Detected Laser Energy Density$_{SP}$ = 60 [W] * 5 [ns] * 2 * 1 / .000720 [m^2] = 0.833 mJ/m^2
Case 100mm: Detected Laser Energy Density$_{SP}$ = 60 [W] * 5 [ns] * 2 * 1 / .000731 [m^2] = 0.821 mJ/m^2
Case 1ft: Detected Laser Energy Density$_{SP}$ = 60 [W] * 5 [ns] * 2 * 1 / .000507 [m^2] = 1.183 mJ/m^2
Case 5ft: Detected Laser Energy Density$_{SP}$ = 60 [W] * 5 [ns] * 1 * 1 / .000212 [m^2] = 1.417 mJ/m^2
Case 10ft: Detected Laser Energy Density$_{SP}$ = 60 [W] * 5 [ns] * 1 * 1 / .000139 [m^2] = 2.153 mJ/m^2
Case 16ft: Detected Laser Energy Density$_{SP}$ = 60 [W] * 5 [ns] * 1 * 1 / .000131 [m^2] = 2.292 mJ/m^2
Case 20ft: Detected Laser Energy Density$_{SP}$ = 60 [W] * 5 [ns] * 1 * 1 / .000125 [m^2] = 2.404 mJ/m^2
Case 30ft: Detected Laser Energy Density$_{SP}$ = 60 [W] * 5 [ns] * 1 * 1 / .000244 [m^2] = 1.227 mJ/m^2
Case 100ft: Detected Laser Energy Density$_{SP}$ = 60 [W] * 5 [ns] * 1 * 1 / .002063 [m^2] = 0.146 mJ/m^2

The single pulse MPE is calculated from Table A1 of IEC 60285-1,

$MPE_{SP} = 5 * 10^{-3} * C_4$ J/ m^2

Where C_4 is derived from Table 10:

$C_4 = 10^{0.002*(\_ - 700)}$

Where _ = 905 [nm]

$C_4 = 2.57$

$MPE_{SP} = 12.85$ mJ/ m^2

<u>Condition 1 Conclusion</u>

Since all Cases are lower than the MPE_{SP}, the Product has no ENOHD for this Condition.

<u>**Condition 2: Average Maximum Permissible Exposure Limit (1 second exposure)**</u>

The average power is calculated similarly to the ENOHD Condition 1, except more lasers overlap in the Pulse Repetition period. The formula for calculating the fixed detector position power is:

[Detected Laser Energy Density$_{SP}$] * [Pulse Repetition Rate] * [Laser Overlap] * [Head Overlap] * [Sequential Duty Cycle] * [Rotation Factor]

where the Laser Overlap is the number of times within the Base Repetition Period a laser emission illuminates the detector. In Cases 4mm, 100mm and 1ft there are 8 separate laser emissions that overlap the same spot size (all lasers within the burst period overlap). In Case 5ft, this number is 2 to account for the maximum overlap within the head as the unit rotates. In the remaining Cases, there is no overlap, so this number is 1.

the Head Overlap is the number of Heads that will cross the fixed position detector in a single rotation. In all Cases less than 20ft, the emissions form the heads may overlap, so this number is 2. In Cases 20ft and above, there is no overlap of left and right heads, so this number is 1.

the Sequential Duty Cycle is how often the Upper Head of the Product is triggered in the system operation. This number is 0.75.

and the Rotation Factor is determined differently from Section 6.1. Since the detector is larger than the spot size, the ratio of the detector diameter to the circumference at the given distance from the output window is used.

Rotation Factor = [Detector Diameter] / [Circumference of Detector Distance of Center of Rotation]

The Rotation Factors are:

Case 14mm:	**50 [mm] / { 2 * * (86 + 14 [mm] }**	**= .0796**
Case 100mm:	**50 [mm] / { 2 * * (86 + 100 [mm] }**	**= .0428**
Case 1ft:	**50 [mm] / { 2 * * (86 + 304.8 [mm] }**	**= .0204**
Case 5ft:	**50 [mm] / { 2 * * (86 + 1524 [mm] }**	**= .0049**
Case 10ft:	**50 [mm] / { 2 * * (86 + 3048 [mm] }**	**= .0025**
Case 16ft:	**50 [mm] / { 2 * * (86 + 4876.8 [mm] }**	**= .0016**
Case 20ft:	**50 [mm] / { 2 * * (86 + 6096 [mm] }**	**= .0013**
Case 30ft:	**50 [mm] / { 2 * * (86 + 9144 [mm] }**	**= .0009**
Case 100ft:	**50 [mm] / { 2 * * (86 + 30480 [mm] }**	**= .0003**

The detected Laser Power Density Calculations is then:

Case 14mm: Det Laser Power$_{av,rot}$ = 0.833 [mJ/m^2] * 31.25 [kHz] * 8 * 2 * .75 * .0796 = 24.87 W/m^2
Case 100mm: Det Laser Power$_{av,rot}$ = 0.821 [mJ/m^2] * 31.25 [kHz] * 8 * 2 * .75 * .0428 = 13.17 W/m^2
Case 1ft: Det Laser Power$_{av,rot}$ = 1.183 [mJ/m^2] * 31.25 [kHz] * 8 * 2 * .75 * .0204 = 9.03 W/m^2
Case 5ft: Det Laser Power$_{av,rot}$ = 1.417 [mJ/m^2] * 31.25 [kHz] * 2 * 2 * .75 * .0049 = 0.66 W/m^2
Case 10ft: Det Laser Power$_{av,rot}$ = 2.153 [mJ/m^2] * 31.25 [kHz] * 1 * 2 * .75 * .0025 = 0.26 W/m^2
Case 16ft: Det Laser Power$_{av,rot}$ = 2.292 [mJ/m^2] * 31.25 [kHz] * 1 * 2 * .75 * .0016 = 0.17 W/m^2

Case 20ft: Det Laser Power$_{av,rot}$ = 2.404 [mJ/m^2] * 31.25 [kHz] * 1 * 1 * .75 * .0013 = 0.07 W/m^2
Case 30ft: Det Laser Power$_{av,rot}$ = 1.227 [mJ/m^2] * 31.25 [kHz] * 1 * 1 * .75 * .0009 = 0.02 W/m^2
Case 100ft: Det Laser Power$_{av,rot}$ = 0.146 [mJ/m^2] * 31.25 [kHz] * 1 * 1 * .75 * .0003 = 0.001 W/m^2

The MPE average power Table A1 (using 10 s emission duration),

MPE_{AV} = 10 * C_4 * C_7 W/m^2

Where C_4 is derived in Condition 1 = 2.57

And C_7 is derived from Table 10 = 1

MPE_{AV} = 25.7 W/m^2

Condition 2 Conclusion

Since all Cases are lower than the MPE_{AV}, the Product has no ENOHD for this Condition.

Condition 3: Repetitive Pulse Maximum Permissible Exposure Limit (10 second exposure)

The calculated emission from ENOHD Condition 1 will be used to check for this Condition.

Case 4mm: Detected Laser Energy Density$_{SP}$ = 0.833 mJ/m^2
Case 100mm: Detected Laser Energy Density$_{SP}$ = 0.821 mJ/m^2
Case 1ft: Detected Laser Energy Density$_{SP}$ = 1.183 mJ/m^2
Case 5ft: Detected Laser Energy Density$_{SP}$ = 1.417 mJ/m^2
Case 10ft: Detected Laser Energy Density$_{SP}$ = 2.153 mJ/m^2
Case 16ft: Detected Laser Energy Density$_{SP}$ = 2.292 mJ/m^2
Case 20ft: Detected Laser Energy Density$_{SP}$ = 2.404 mJ/m^2
Case 30ft: Detected Laser Energy Density$_{SP}$ = 1.227 mJ/m^2
Case 100ft: Detected Laser Energy Density$_{SP}$ = 0.146 mJ/m^2

We must determine the number of laser emissions that will illuminate the detector over a period of 10 seconds to calculate to $MPE_{train,\ SP}$. This number shall be calculated using the following formula:

N = [Pulse Repetition Rate] * [Laser Overlap] * [Head Overlap] * [Sequential Duty Cycle] * [Rotation Factor] * [Illumination Duration]

$C_5 = N^{-0.25}$

However, if multiple optical pulses occur within an T_i (18us period as defined by Table 3), they are considered as a single pulse to determine N, and the energies of the individual pulses are added to compared to MPE of T_i . This is the case in Cases 14mm, 100mm and 1ft. For these Cases the number is calculated using the following formula:

N = [Rotation Factor] * [Sequential Duty Cycle] * [Head Overlap] * [Illumination Duration] / [T_i]

$C_5 = N^{-0.25}$

Case 14mm: C_5 = {.0796 * 0.75 * 2 * 10 [s] / 18 [us]}$^{-0.25}$ = .0623
Case 100mm: C_5 = {.0428 * 0.75 * 2 * 10 [s] / 18 [us]}$^{-0.25}$ = .0728
Case 1ft: C_5 = {.0204 * 0.75 * 2 * 10 [s] / 18 [us]}$^{-0.25}$ = .0876
Case 5ft: C_5 = {31.25 [kHz] * 2 * 2 * 0.75 *.0049 * 10[s]}$^{-0.25}$ = .121
Case 10ft: C_5 = {31.25 [kHz] * 1 * 2 * 0.75 *.0025 * 10[s]}$^{-0.25}$ = .170
Case 16ft: C_5 = {31.25 [kHz] * 1 * 2 * 0.75 *.0016 * 10[s]}$^{-0.25}$ = .191
Case 20ft: C_5 = {31.25 [kHz] * 1 * 1 * 0.75 *.0013 * 10[s]}$^{-0.25}$ = .239

Case 30ft: C_5 = {31.25 [kHz] * 1 * 1 * 0.75 *.0009 * 10[s]}$^{-0.25}$ = .262
Case 100ft: C_5 = {31.25 [kHz] * 1 * 1 * 0.75 *.0003 * 10[s]}$^{-0.25}$ = .345

The limits are then calculated by:

$MPE_{train,\ SP}$ = MPE_{SP} * C_5 (where MPE_{SP} = 12.85 mJ/ m^2 , from Condition 1) for non-burst (single) pulses

And,
$MPE_{train,\ 18us}$ = MPE_{18us} * C_5 for Cases when multiple emissions occur in an 18us period

where
$MPE_{train,\ 18us}$ = 18 * $t^{0.75}$ * C_4 J/m^2 (from IEC 60285-1 Table A1)
where t = 18 us and C4 = 2.57
= 12.78 mJ/m^2

MPE Calculation is:

Case 14mm: $MPE_{train,\ 18us}$ = 12.78 mJ/m^2 * .0623 = 0.80 mJ/m^2
Case 100mm: $MPE_{train,\ 18us}$ = 12.78 mJ/m^2 * .0728 = 0.93 mJ/m^2
Case 1ft: $MPE_{train,\ 18us}$ = 12.78 mJ/m^2 * .0876 = 1.12 mJ/m^2
Case 5ft: $MPE_{train,\ SP}$ = 12.85 mJ / m^2 * .121 = 1.56 mJ/m^2
Case 10ft: $MPE_{train,\ SP}$ = 12.85 mJ / m^2 * .170 = 2.20 mJ/m^2
Case 16ft: $MPE_{train,\ SP}$ = 12.85 mJ / m^2 * .191 = 2.46 mJ/m^2
Case 20ft: $MPE_{train,\ SP}$ = 12.85 mJ / m^2 * .239 = 3.08 mJ/m^2
Case 30ft: $MPE_{train,\ SP}$ = 12.85 mJ / m^2 * .262 = 3.37 mJ/m^2
Case 100ft: $MPE_{train,\ SP}$ = 12.85 mJ / m^2 * .345 = 4.43 mJ/m

Case	Condition 3 MPE_{train}	Single Pulse Detected Laser Energy Density	MPE Pass/Fail
14mm	0.80 mJ/m^2	0.833 mJ/m^2	Fail
100mm	0.93 mJ/m^2	0.821 mJ/m^2	Pass
1ft	1.12 mJ/m^2	1.183 mJ/m^2	Fail
5ft	1.56 mJ/m^2	1.417 mJ/m^2	Pass
10ft	2.20 mJ/m^2	2.153 mJ/m^2	Pass
16ft	2.46 mJ/m^2	2.292 mJ/m^2	Pass
20ft	3.08 mJ/m^2	2.404 mJ/m^2	Pass
30ft	3.37 mJ/m^2	1.227 mJ/m^2	Pass
100ft	3.08 mJ/m^2	0.146 mJ/m^2	Pass

TABLE 2
Condition 3 Calculated MPE vs Single Pulse Laser Energy Density vs Distance

Condition 3 Conclusion

Since the 1 ft Case exceeds the MPE limit, and 5 feet and beyond are all lower than the MPE, the ENOHD for Condition 3 is 5 feet.

Condition 3B: Repetitive Pulse Accessible Emission Limit (18 us exposure)

Since there are multiple pulses within an 18 us period, we must also check that the total energy in the 18 us period does not exceed the AEL for 18us. This condition only occurs in

Cases 14mm, 100mm and 1ft. Since each of these Cases are already inside the ENOHD per Condition 3, no calculations need to be conducted for Condition 3B.

6.6 CONCLUSION

For the situation of viewing the Product with viewing optics (which is not recommended), since the Product exceeds the Condition 3 MPE at one foot from the output window for this situation, but is within the MPE limit at five feet, the ENOHD for this Product is 5 feet.

PART 7: COMPLIANCE WITH THE PERFORMANCE REQUIREMENTS

7.1 Protective housing - Required for all laser products [1040.10(f)(1)]

7.1.1 Describe the product's protective housing and how it serves to prevent unnecessary human access to laser radiation.

The laser is mounted inside of a solid aluminum tube. The laser only fires forward. Each laser tube is securely mounted inside a larger housing that prevents unnecessary human access.

Is additional information attached? (**X**)Yes ( )No **See Figure 4.**

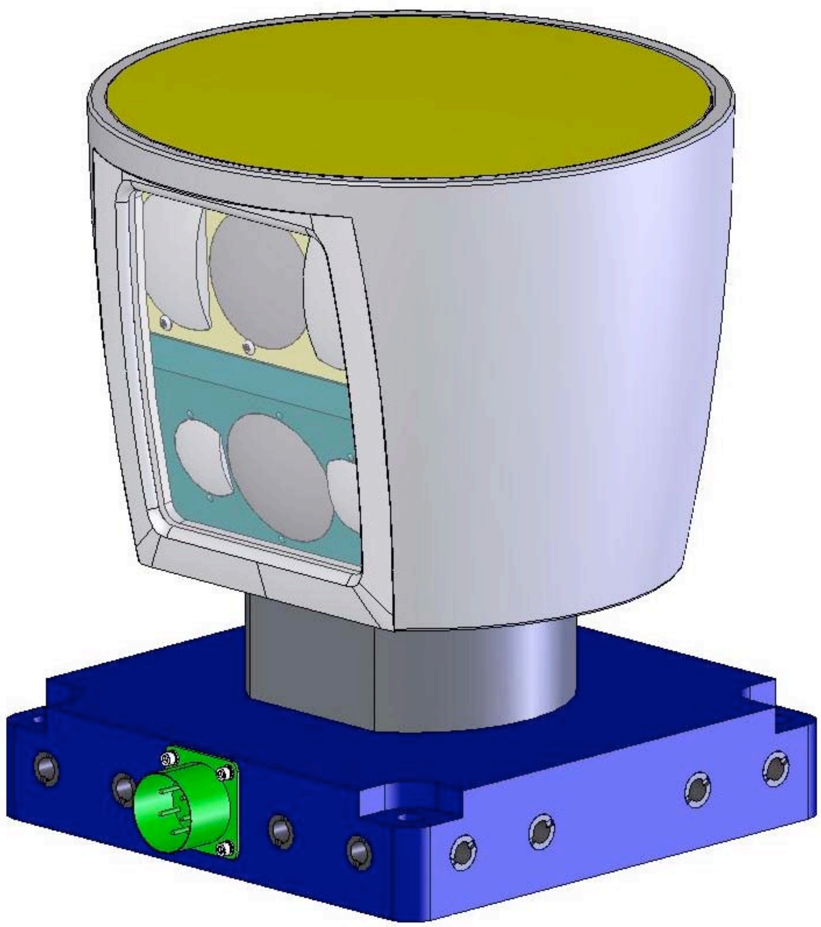


FIGURE 4

7.1.2 Describe how the protective housing prevents access to unnecessary collateral radiation.

The laser is mounted inside of a solid tube. Laser light has only one exit; therefore collateral radiation is not possible.

Is additional information attached? ( )Yes (**X**)No

7.2 Safety interlocks - Applicable for all laser products [1040.10(f)(2)(i)]

7.2.1 Provide a detailed mechanical diagram showing the location of each interlock incorporated into the laser product for radiation safety.

Is a mechanical diagram attached? (**X**)Yes ( )No
Describe each interlock and explain how each such interlock prevents access to laser and/or collateral radiation when each portion of the protective housing is opened.

This product contains an electro-mechanical interlock. The interlock works on centrifugal force and prevents the laser from firing when the Product is not rotating.

Is additional information attached? ( )Yes (**X**)No

7.2.2 Provide an electrical block diagram illustrating the logic of the interlock system.

Is an electrical diagram attached? (**X**)Yes ( )No

See Figure 5

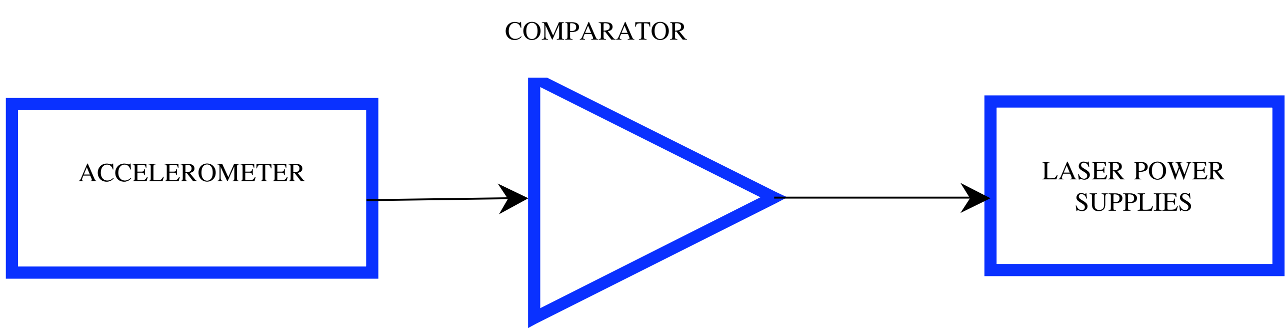


FIGURE 5
ELECTRO-MECHANICAL LASER INTERLOCK BLOCK DIAGRAM

7.2.3 For each safety interlock, state whether actuation is intended during operation, maintenance, service, or any combination thereof.

The actuation of the interlock is intended to prevent any safety issues during normal operation or in the event of a system failure.

Is additional information attached? ( )Yes (**X**)No

7.2.4 For each safety interlock, state the highest level of laser radiation and collateral radiation to which access is prevented.

In the event the product does not spin or does not properly pulse, the safety interlock will prevent any collateral radiation.

7.3 Defeatable safety interlocks - Applicable to all laser products [1040.10(f)(2)(ii) and (iii)]

7.3.1 Identify which safety interlocks are designed to allow defeat and describe how they operate.

The safety interlock can only be defeated when the product cover is removed. This should only be done at by the manufacturer. Once removed, a jumper must be used to short J34 pins 1 and 2 to allow the lasers to operate as if the unit was rotating.

Is additional description attached? ( )Yes (**X**)No

7.3.2 For each safety interlock designed to allow defeat, state whether defeat is intended during operation, maintenance, service, or any combination thereof.

The safety interlock is only intended during manufacture, service and maintenance. It is not accessible to the user in the final Product.

7.3.3 For each safety interlock designed to allow defeat, describe how replacement of a removed or displaced portion of the protective housing is not possible while the safety interlocks are defeated.

Protective Housing is only replaced at the Manufacturer.

7.3.4 For each safety interlock designed to allow defeat, describe the means of providing a visible or audible indication of defeat.

If the safety interlock is defeated, LED D15 will illuminate, indicating power is available to the laser assemblies.

7.4 Safety interlock failure - Applicable to all required safety interlocks [1040.10(f)(2)(iii)] that prevent access to Class IIIb or IV levels of laser radiation.

This product is a Class IM device

7.4.1 Describe how each safety interlock is "fail-safe," i.e., precludes removal or displacement of the interlocked portion of the protective housing upon failure of the safety interlock or is redundant
This product contains a single interlock mechanism which allows the laser power supplies to turn on only when the Product is rotating at a sufficient speed. The typical speed at which this circuit will turn on the laser power supplies is 360 revolutions per minute. This accelerometer is located within the enclosure and is not accessible by the user in the Product.

Are electrical/mechanical diagrams or additional information attached?
(**X**)Yes ( )No

See Figure 5.

7.4.2 Describe the possible modes of failure of each safety interlock and the resultant effect upon the radiation safety of the laser product.

The accelerometer could provide a false high or low output reading.

If the false high failure were to occur, the Product will still rotate when power is applied, but the lasers would turn on sooner than the design threshold in the spin up cycle as the Product begins to rotate. As long as the Product rotates, the Product is still Class 1M.

In the false low failure mode, the lasers will never turn on, even when the Product rotates at full speed. So the product will not function, and it will not cause an emission hazard

Is additional information attached? ( )Yes (**X**)No

7.4.3 State the rating of each safety interlock, including the number of operational cycles before failure.

The accelerometer is specified to operate from -120g to +120g. It is rated to withstand a maximum acceleration of 4000 g's. The Mean-Time-to-Failure for the accelerometer is 1.4 * 10^9 hours.

7.5 Remote interlock connector - Applicable to Class IIIb or IV laser systems [1040.10(f)(3)]

Not Applicable

7.5.1 Describe the electrical and mechanical construction and operation of the remote interlock connector. Give its circuit and physical location.

Not Applicable

Are electrical/mechanical diagrams or additional information attached? ( )Yes (**X**)No

Not Applicable

7.5.2 Record the open-circuit electrical potential difference between the terminals of the remote interlock connector.
____**N/A**______ Volts

Not Applicable

7.6 Key control - Required for Class IIIb or IV laser systems [1040.10(f)(4)]

Not Applicable

7.6.1 Describe the electrical and mechanical construction of the key-actuated master control.

Not Applicable

Are electrical/mechanical diagrams or additional information attached? ( )Yes (**X**)No

7.6.2 Describe the function of the key-actuated master control and how it renders the laser inoperable when the key is removed.

Not Applicable

Are electrical/mechanical diagrams or additional information attached? ( )Yes (**X**)No

7.6.3 Is the key removable in the "On" position?

Not Applicable

( )Yes ( )No **N/A**

7.7 Laser radiation emission indicator - Required for Class II, IIIa, IIIb, or IV laser systems [1040.10(f)(5)]

Not Applicable

7.7.1 Describe in detail the mechanical and electrical characteristics of all emission indicators installed pursuant to Section 1040.10(f)(5)(i) or (ii) and give their locations. Note that if the energy source and remote controller(s) are separable by more than 2 meters, then each control must have an emission indicator.

Not Applicable

Are electrical/mechanical diagrams or additional information attached?
( )Yes (**X**)No

7.7.2 Record the length of time each emission indicator of Class IIIb and IV laser systems is actuated prior to the emission of accessible laser radiation.
Emission indicator delay: _____ sec

Not Applicable

7.8 Protective eyewear - Applicable to Class II, IIIa, IIIb or IV laser systems [1040.10(f)(5)(iv)]
State whether protective eyewear is supplied or recommended for use with the laser system. If so, confirm that any visible emission indicator can be clearly seen through the protective eyewear.
Not Applicable

Is protective eyewear supplied?
( )Yes
(**X**)No

Not Applicable

Is it recommended?
( )Yes
( )No

Not Applicable

Can visible emission indicators be seen through eyewear?
( )Yes
( )No

Not Applicable

7.9 Beam attenuator - Required for Class II, IIIa, IIIb or IV laser systems [1040.10(f)(6)]

Not Applicable

7.9.1 For each beam attenuator, describe the mechanical and electrical characteristics and how, when actuated, the attenuator prevents access by any part of the human body to all laser and collateral radiation in excess of the accessible emission limits of Class I and Table VI.

Not Applicable

Are electrical/mechanical diagrams or additional information attached?
( )Yes (**X**)No

7.9.2 Describe the permanency of attachment of each beam attenuator.

Not Applicable

NOTE: You may apply for approval of alternate means of providing this protection if a beam attenuator is inappropriate to the product.

7.10 Location of controls - Applicable to Class II, IIIa, IIIb or IV laser products [1040.10(f)(7)] Explain how the location of each of the operation and adjustment controls of the laser product is such that human exposure to laser or collateral radiation in excess of the accessible emission limits of Class I and Table VI is prevented during operation or adjustment of such controls.

Not Applicable

7.11 Viewing optics - Applicable to all laser products [1040.10(f)(8)]

7.11.1 State whether all laser and collateral radiation accessible by virtue of viewing optics, view ports, and display screens incorporated into the reported model of laser product is less than the accessible emission limits of Class I and Table VI during operation and maintenance. Include with your calculations pertinent attenuation factors, window transmission characteristics, etc.

Yes, the emission limits are below that of Class I. The Product is not intended for use with any viewing optics, so the Product is classified as Class IM.

Are electrical/mechanical diagrams or additional information attached?
( )Yes (**X**)No

REMINDER: Report in Part 5 the location and identification of laser and collateral radiation made accessible by viewing optics, viewports, and display screens. In Part 6, report the highest levels.

7.11.2 Describe in detail, using diagrams or photographs and radiation transmission or reflection spectra, each shutter or variable attenuator incorporated into viewing optics, viewport, or display screen. Describe how exposure of the eye to laser or collateral radiation in excess of the accessible emission limits of Class I and Table VI is prevented whenever the shutter is opened or the attenuator is varied.

N/A. This Product does not have a shutter and does not have an attenuator. The product does not have collateral radiation.

Are diagrams/photographs or additional information attached?
( )Yes (**X**)No **N/A**

7.11.3 Describe how exposure of the eye to laser or collateral radiation in excess of the accessible emission limits of Class I and Table VI is prevented in the event of failure of the shutter or variable attenuator, as required by Section 1040.10(f)(8)(ii).

N/A. This product does not have a shutter and does not have an attenuator. This product does not have collateral radiation.

Are diagrams or additional information attached?
( )Yes (**X**)No

7.12 Scanning safeguard - Required for certain laser products with scanned laser radiation [1040.10(f)(9)].
Describe the mechanical, electrical, and functional characteristics of any required scan failure safeguard. Include calculations to show that the safeguard's reaction time is adequate for compliance with this section.

The scanning safeguard consists of a centrifugal switch.

In the event of a system failure, the spin down time of the laser assembly is approximately 10 seconds. The centrifugal switch has a reaction time of 10 milliseconds therefore this centrifugal switch has a superior response time.

Are electrical/mechanical diagrams, calculations, or additional information attached?
( )Yes (**X**)No

NOTE: A safeguard is required when scan failure would cause the product to exceed the emission limits of the class of the product, or in the case of Class IIIb or IV laser products would cause the accessible emission limits of Class IIIa to be exceeded.

7.13 Manual reset - Applicable to Class IV laser systems manufactured after August 20, 1986. Provide the circuit and physical description and location of the means provided to require manual restart following interruption of emission caused by power failure of at least 5 seconds or deactivation through the remote interlock connector.

Not Applicable

7.14 Medical laser product - Applicable to Class III or IV medical laser products intended for in-vivo surgical, therapeutic, or diagnostic irradiation of the human body.

NOTE: The requirement in section 1040.11(a) does not apply to visible aiming beams less than the accessible emission limits of Class IIIa except for ophthalmic indications.

If your product is a Class III or IV medical laser product, provide the following information:

7.14.1 Describe the means incorporated into the product to measure the level of laser radiation intended for irradiating the human body; include circuit diagrams and/or optical system diagrams.

Not Applicable

Are electrical/mechanical diagrams, calculations, or additional information attached?
( )Yes ( )No

Not Applicable

7.14.2 Specify the uncertainty in the measurement system and describe the method by which it was derived.

Not Applicable

Are calculations or additional information attached?
( )Yes ( )No

Not Applicable

7.14.3 Is the displayed power/energy level measured at the point of delivery or earlier and then calculated? If the displayed level is calculated incorporating system constants, losses, attenuation factors, etc. please provide calculations to demonstrate accurate calibration of the delivered beam to within + or - 20%, as required by 1040.11(a)(1).

Not Applicable

Are calculations or additional information attached?
( )Yes ( )No

Not Applicable

7.14.4 Are procedures and a schedule for recalibration of the measurement system included in the user instructions?

Not Applicable

( )Yes ( )No
If yes, please identify location in the user instructions:

7.15 Surveying, leveling, or alignment laser products - Is the product a surveying, leveling, or alignment laser product?
( )Yes
(**X**)No

If yes, then it is subject to the requirements of section 1040.11(b). If the product's class exceeds Class IIIa then an approved variance from the performance requirements in this section would be necessary prior to introduction into commerce. Procedures for applying for a variance are given in section 1010.4, and described in the Compliance Guide, page 13.

7.16 Demonstration laser products - Is the product a demonstration laser product?
( )Yes
(**X**)No

If yes, then it is subject to the requirements of section 1040.11(c). If the product's class exceeds Class IIIa then an approved variance from the performance requirements in this section would be necessary prior to introduction into commerce. Procedures for applying for a variance are given in the Compliance Guide, pages 13 and 16-22.
An Application for a Variance from 21 CFR 1040.11(c) for a Laser Light Show, Display, or Device (form FDA 3147) must be submitted, following the instructions on the form. A Laser Light Show report may also be required if you intend to produce shows or displays with Class IIIb or Class IV demonstration laser products. The Reporting Guide for Laser Light Shows and Displays should be filled out and submitted along with this report and the variance application, following the instructions in each document.

Not Applicable

7.16.1 Is a Variance application being submitted along with this report?
( )Yes - date of submission: ________ ( )No

Not Applicable

7.16.2 Is a Laser Light Show report being submitted along with this report?
( )Yes - date of submission: ________ ( )No

Not Applicable

PART 8: QUALITY CONTROL TESTS AND TESTING PROCEDURES

8.1 Attach, and identify as attachments to Part 8, samples of documents that describe, specify, or relate to procedures or tests used to ensure compliance of your reported product with the standard, including compliance with all performance, labeling, and informational requirements. These may include:

(**X**) specification controls for critical components,
( ) manufacturing and assembly control procedures,
( ) inspection and test control procedures,
( ) assembly and test traveler forms,
(**X**) inspection and test reports and checklists, and/or
( ) other(s) ____
(specify)

See Appenidx B for Laser Diode Specification (critical component)
See Appendiz C for Inspection Check List

8.2 If formal quality control and testing procedures have not been implemented or are not sufficient to assure that your product(s) will comply with the standard, explain how you assure that your products comply and submit supporting documentation.

NOTE: Section 1010.2(c) requires that certification be based on a test, in accordance with the standard, of each unit or on a program in accordance with good manufacturing practices. Failure to maintain an adequate testing program may result in disapproval of the program by CDRH.

PART 9: LIFE AND ENDURANCE TESTING

Describe those tests and controls used to ensure that the reported product will remain in compliance with the Federal laser product performance standard during its useful life. Items to be addressed include:

9.1 Dimensional stability and rigidity of mechanical parts and assemblies such as housings and mounts

There should be no deviation in the operation of the final Product of the housing or mechanical assemblies. Figures 6.1 thru 6.7 show the housing and internal assemblies.

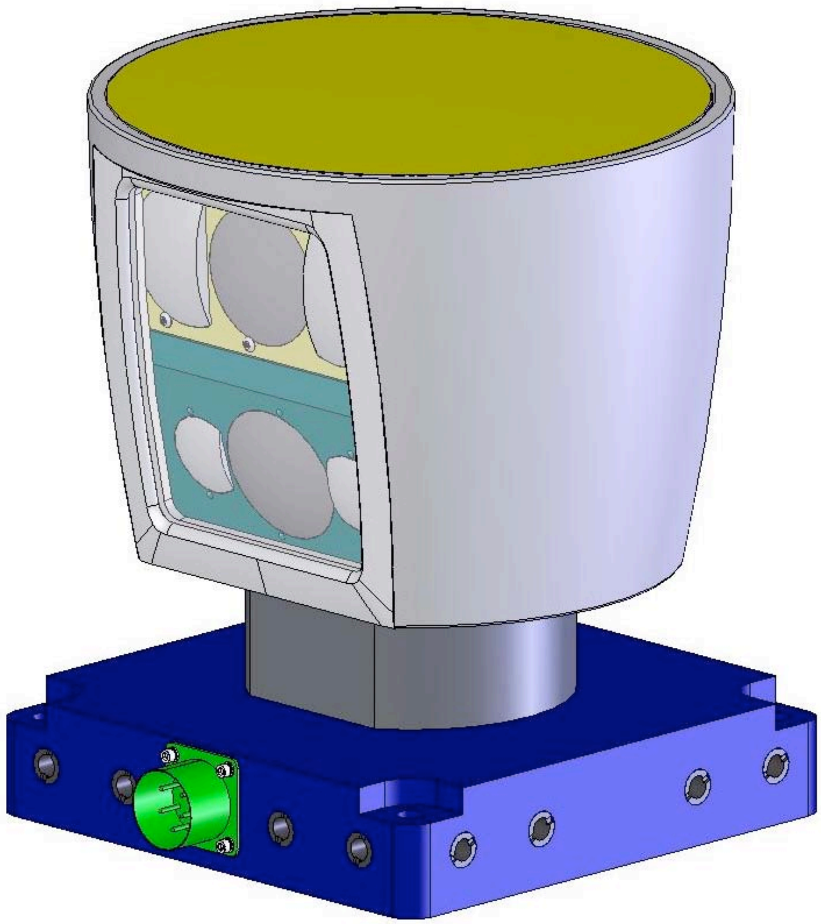


FIGURE 6.1

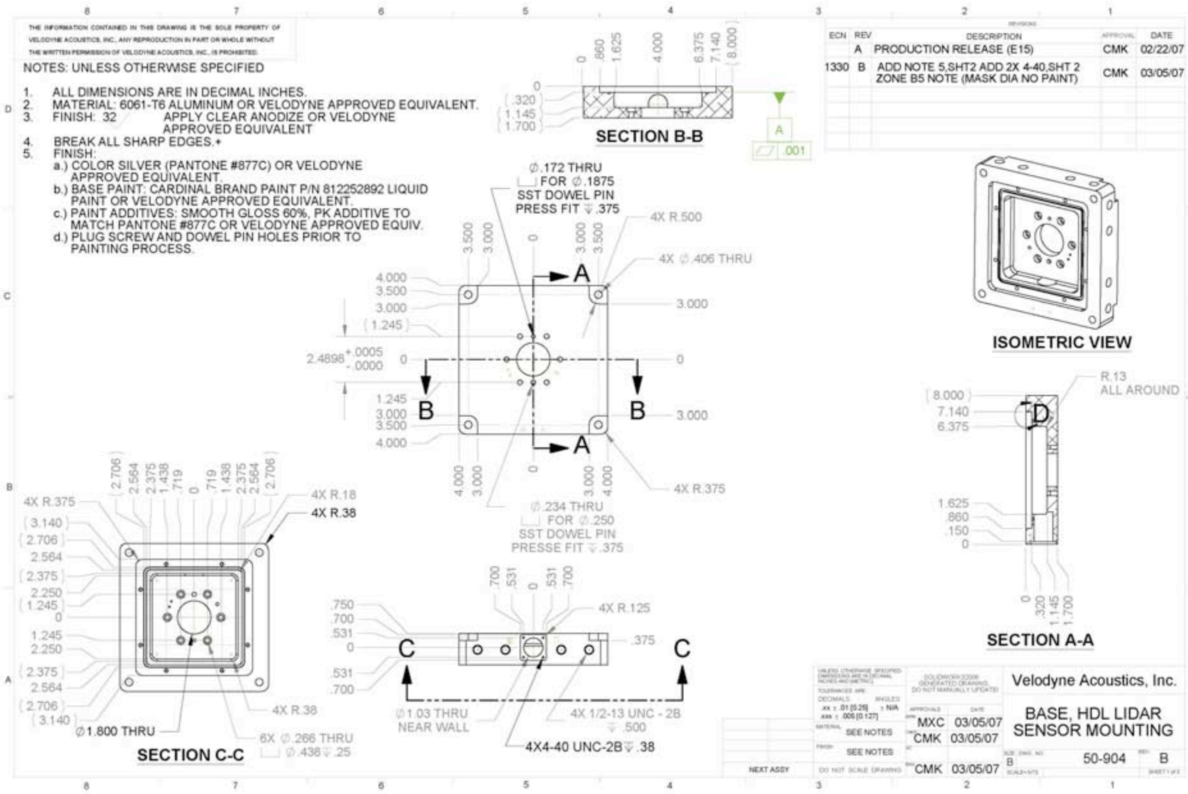


FIGURE 6.2

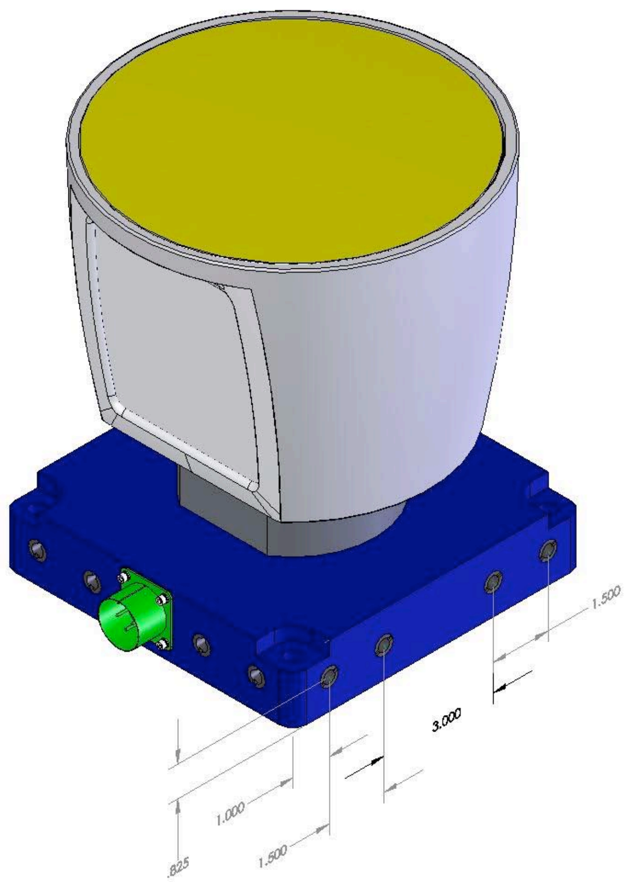


FIGURE 6.3

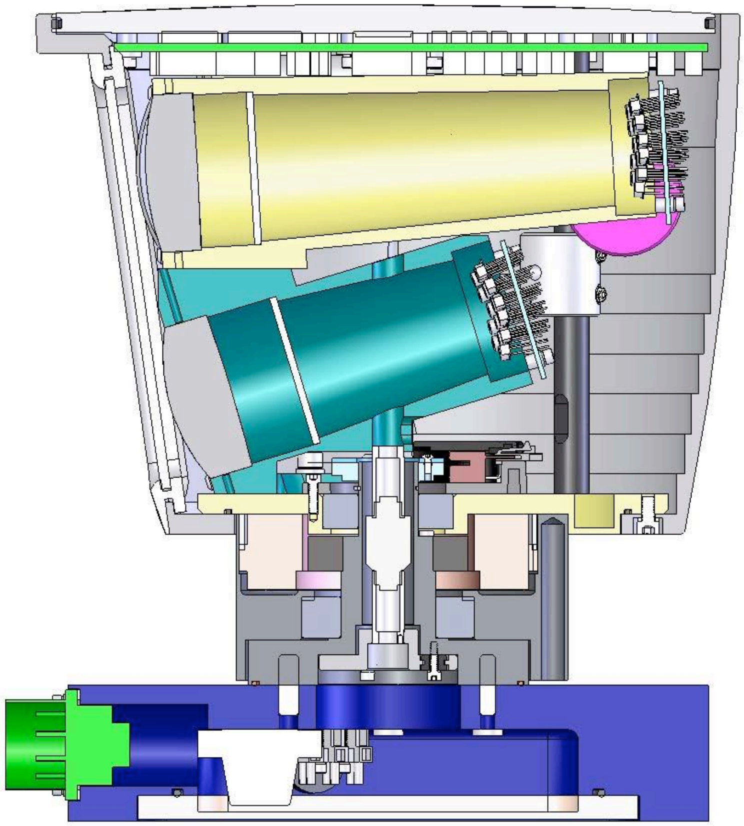


FIGURE 6.4

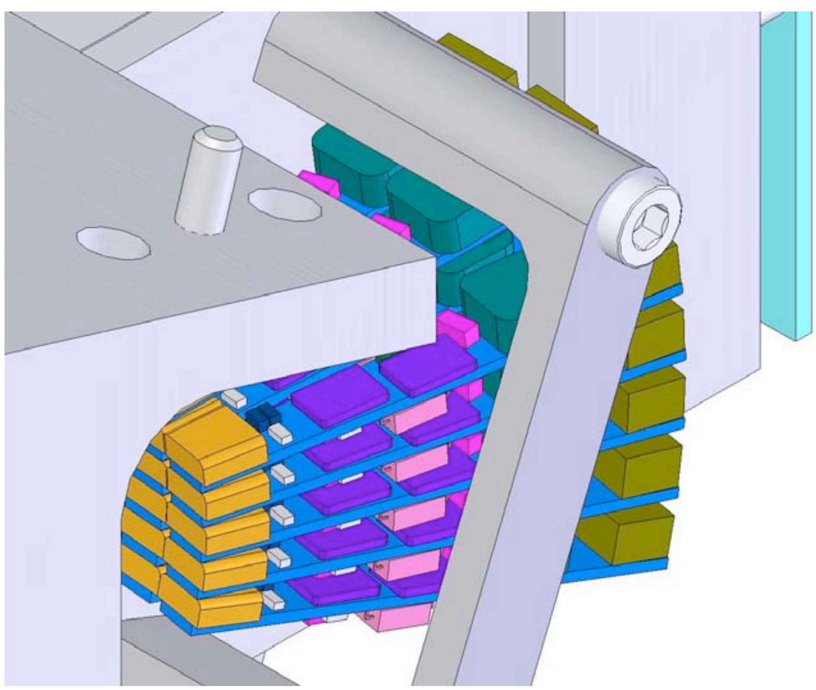


FIGURE 6.5

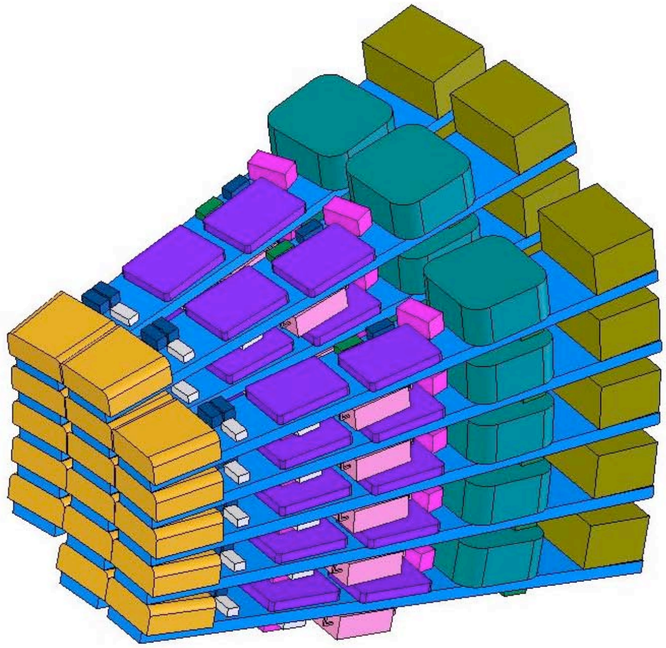


FIGURE 6.6

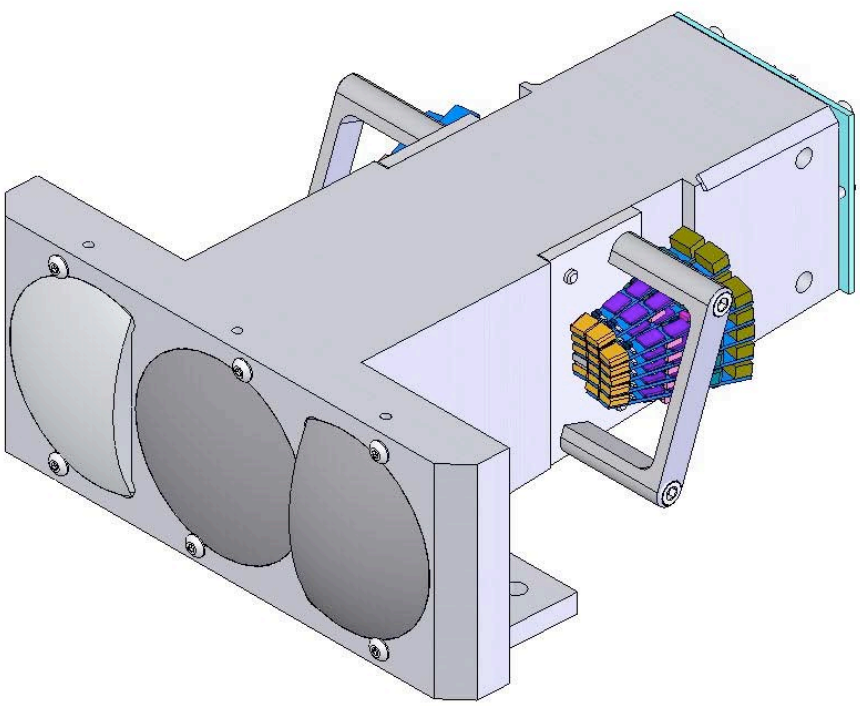


FIGURE 6.7

Is additional information/documentation attached?
( )Yes ( )No

9.2 Design and ratings of electrical and electronic components

Laser Datasheet attached as Appendix A

Is additional information/documentation attached?
(**X**)Yes ( )No

9.3 Environmental stability of components such as filter materials, coatings, and adhesives

Not applicable.

Is additional information/documentation attached?
( )Yes (**X**)No

9.4 Design and testing of features designed to meet Federal laser product performance requirements

Is additional information/documentation attached?
( )Yes (**X**)No

9.5 Other factors that might affect your product's radiation safety

Not applicable

Is additional information/documentation attached?
( )Yes ( )No

NOTE: Maintenance and/or service instructions must include schedules for maintenance and replacement of those components related to the compliance of the product that may be expected to be replenished or replaced during the life of the product.

PART 10: INSTRUMENTATION AND CALIBRATION

Describe those tests and controls used to ensure that the reported product will remain in compliance with the Federal laser product performance standard during its useful life. Items to be addressed include:

10.1 List the instruments you use to determine compliance of the reported product with the standard. Describe these instruments or provide copies of specification sheets. Identify each detector's aperture size, if applicable.

Not applicable. However, a Sony CCD-TRV28 infrared vision camera was used to verify the calculations that were performed earlier in this report. The camera provided the laser image pattern and it was used to determine the point of maximum intensity and thus verify the calculations.

Is additional information attached? ( )Yes (**X**)No

10.2 Indicate how the measurement system collects or accounts for the total radiant energy or power specified in Section 1040.10(e).

Not Applicable

Is additional information attached? ( )Yes (**X**)No

10.3 Provide a measurement error analysis (for all sources of error identified) and an uncertainty statement for all measurement data reported.

Not Applicable

Is additional information attached? ( )Yes ( )No

NOTE: If it is clear from the measurement data, including the total estimated uncertainty, that the levels are well below the applicable class limit, then an error analysis and uncertainty statement are not required. For, example, an error analysis and uncertainty statement would not be required for a 1.5 milli watt HeNe laser product classified in Class IIIa.

10.4 Provide instrument calibration schedules and indicate how your instruments are calibrated (e.g., calibrated by your company against a working standard, returned to the manufacturer of the instrument, sent to an independent calibration laboratory).

Not Applicable

Is additional information attached? ( )Yes ( )No

NOTE: If your laser product operates at a level closely approaching a specified limit, high accuracy and traceability to the National Institute of Standards and Technology (previously known as the National Bureau of Standards) are important.

APPENDEX A – HDL 64E USER'S MANUAL

HDL™-64E

USER'S MANUAL

High Definition Lidar™ Sensor

IMPORTANT SAFETY INSTRUCTIONS

Caution

To reduce the risk of electric shock, do not remove cover (or back). No user-serviceable parts inside. Refer servicing to qualified service personnel.

The lightning flash with arrowhead symbol is intended to alert the user to the presence of uninsulated "dangerous voltage" within the product's enclosure that may be of sufficient magnitude to constitute a risk of electric shock to persons.

The exclamation point symbol is intended to alert the user to the presence of important operating and maintenance (servicing) instructions in the literature accompanying the product.

1. **Read Instructions** — All safety and operating instructions should be read before the product is operated.
2. **Retain Instructions** — The safety and operating instructions should be retained for future reference.
3. **Heed Warnings** — All warnings on the product and in the operating instructions should be adhered to.
4. **Follow Instructions** — All operating and use instructions should be followed.
5. **Heat** — The product should be situated away from heat sources such as radiators, heat registers, stoves, or other products that produce heat.
6. **Power Sources** — The product should be connected to a power supply only of the type described in the operating instructions or as marked on the product.
7. **Cleaning** — The product should be cleaned only as recommended by the manufacturer.
8. **Nonuse Periods** — The power connection to the product should be disconnected when left unused for a long period of time.
9. **Object and Liquid Entry** — Care should be taken so that objects do not fall and liquids are not spilled onto the enclosure.
10. **Damage Requiring Service** — The product should be serviced by qualified service personnel when:
    a. The product does not appear to operate normally or exhibits a marked change in performance.
    b. The product has been dropped or damaged.
11. **Servicing** — The user should not attempt to service the product beyond what is described in the operating instructions. All other servicing should be referred to qualified service personnel.

INVISIBLE LASER RADIATION
DO NOT VIEW DIRECTLY
WITH OPTICAL INSTRUMENTS
CLASS 1M LASER PRODUCT

Table of Contents

INTRODUCTION

Congratulations on your purchase of a Velodyne HDL-64E High Definition Lidar Sensor. This product represents a breakthrough in sensing technology by providing exponentially more information about the surrounding environment than previously possible.

This guide first covers installation and wiring, then addresses output packet construction and interpretation, and finally discusses the serial interface to the unit and software updates.

This manual is undergoing constant revision and improvement – check **www.velodyne.com/lidar** for updates.

Each shipment contains:

- HDL-64E sensor
- Wiring harness
- Mounting tool pouch
- CD with user manual, calibration file (db.XML) and DSR viewer

PRINCIPLES OF OPERATION

The HDL-64E operates on a rather simple premise: instead of a single laser firing through a rotating mirror, 64 lasers are mounted on upper and lower blocks of 32 lasers each and the entire unit spins. This design allows for 64 separate lasers to each fire thousands of times per second, providing exponentially more data points per second and a much richer point cloud than conventional designs. The unit inherently delivers a 360-degree horizontal field of view (FOV) and a 26.8 degree vertical FOV.

Additionally, state-of-the-art signal processing and waveform analysis are employed to provide high accuracy, extended distance sensing and intensity data. The HDL-64E is rated to provide usable returns up to 120 meters.

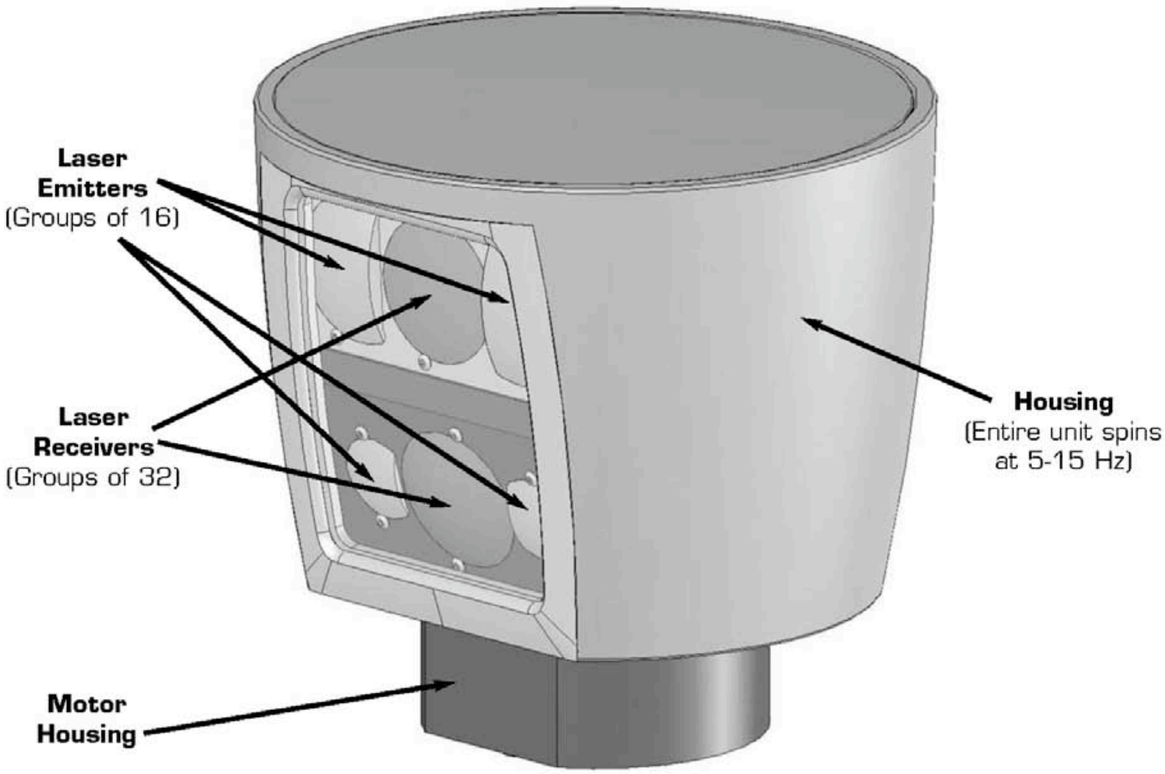


Figure 1. HDL-64E design overview.

The HDL-64E employs a direct drive motor system — there are no belts or chains in the drive train.

INSTALLATION OVERVIEW

Front/Back Mounting

The HDL-64E base provides two mounting options: side mount and top mount. See Figure 2 for front/back mounting options, Figure 3 for side/side mounting, and Figure 4 for top mounting instructions.

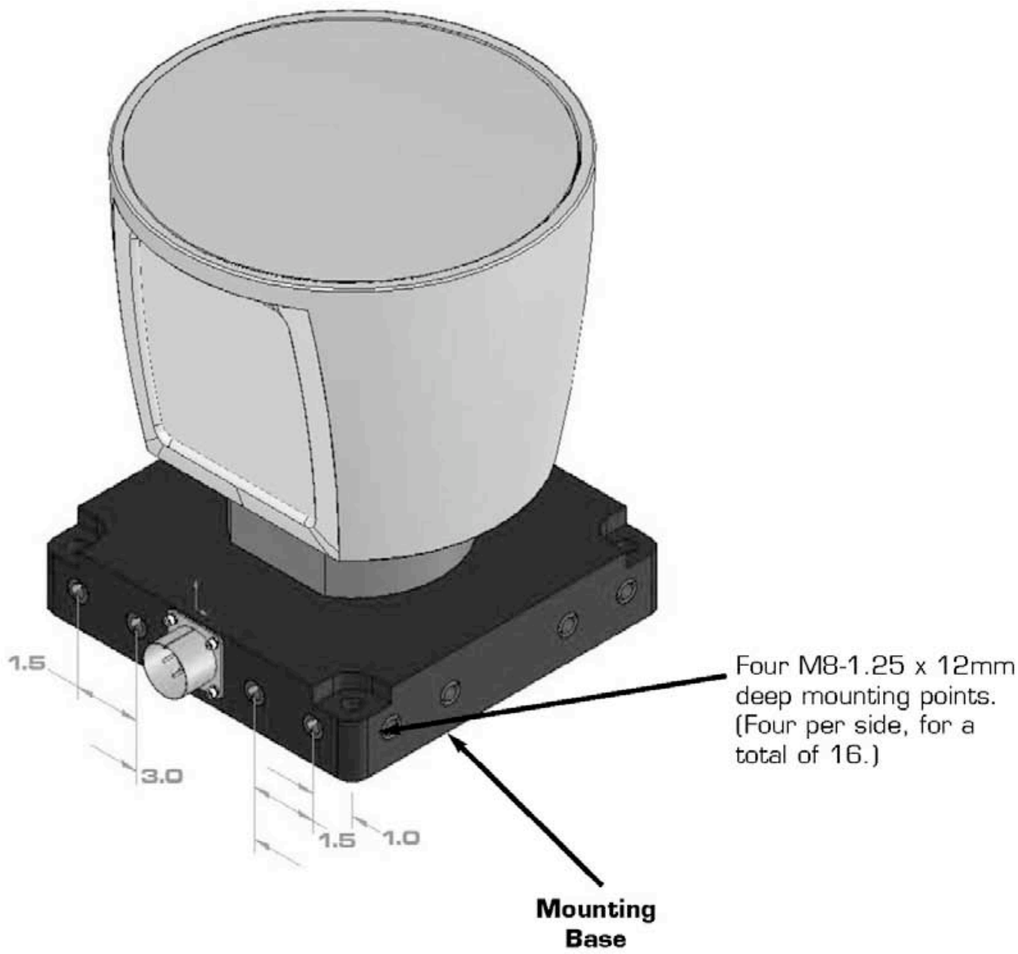


Figure 2. Front and back HDL mounting illustration.

See Figure 2. This figure shows the HDL-64E's base plate screw locations with threaded inserts for standard M8 hardware.

Side Mounting

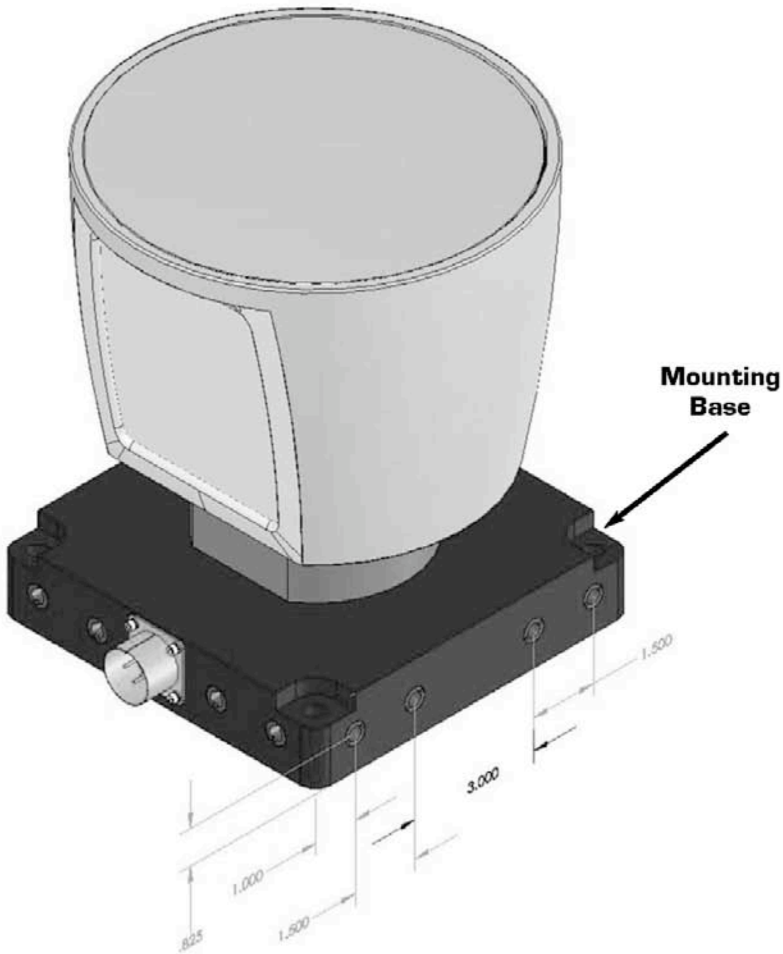


Figure 3. Side/side HDL mounting illustration.

Top Mounting

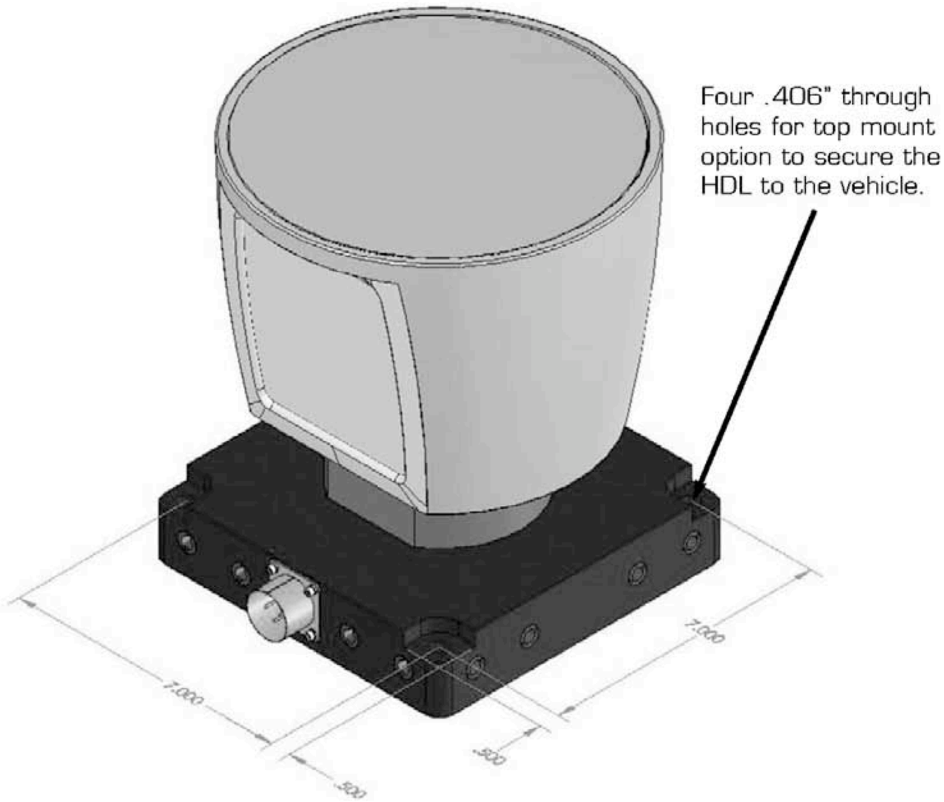


Figure 4. HDL top mounting illustration.

Figure 4 shows the location of four .406" thru holes for top mounting.

For all mounting options, be sure the HDL-64E is mounted securely to withstand vibration and shock without risk of detachment. The unit need not be shock proofed — it is designed to withstand standard automotive G-forces.

The HDL-64E is weatherproofed to withstand wind, rain, and other adverse weather conditions. The spinning nature of the HDL-64E helps the unit shed excess water from the front window that could hamper performance.

Wiring

The HDL-64E comes with a pre-wired connector, wired with power, DB9 serial, and standard RJ-45 Ethernet connectors.The connector wires are approximately 25' in length.

Power. Connect the red and black wires to vehicle power. Be sure red is positive polarity. THE HDL-64E IS RATED ONLY FOR 12 VOLTS. Any voltage applied over 16 volts could damage the unit. Expect the unit to draw 4-6 amps during normal usage.

NOTE: The HDL-64E does not have a power switch. It spins whenever power is applied. The HDL-64E has a lockout circuit that prevents its lasers from firing at low RPMs.

Ethernet. This standard Ethernet connector is designed to connect to a standard PC. See the next section on usage for UDP packet formats.

Serial Interface. The connector also features an RS-232 DB9 serial connector. This connector allows for a firmware update to be applied to the HDL-64E (Velodyne may release firmware updates from time to time). It also accepts commands to change the RPM of the unit.

Cable Diagram. If you wish to wire your own connector, refer to Appendix A for a layout of the wiring pins.

USAGE

Data Packet Construction

The HDL-64E outputs UDP Ethernet packets. Each packet contains a data payload of 1206 bytes that consists of 12 blocks of 100-byte firing data followed by six bytes at the end of each packet that contains a spin counter and firmware version information. Each packet can be for either the upper or lower laser banks (called "laser blocks") - each bank contains 32 lasers. The packet format is as follows:

2 bytes of header info. This header indicates whether the packet is for the upper block or the lower block. The upper block will have a header of 0xEEFF and the lower block will have a header of 0xDDFF.

2 bytes of rotational info. This is an integer between 0 and 35999. Divide this number by 100 to get degrees from 0.

32 laser returns broken into 3 bytes each. Each return contains two bytes of distance information in .2 centimeter increments, and one byte of intensity information (0 – 255, with 255 being the most intense return). A zero return indicates no return up to 65 meters.

Six status bytes that alternate between packets. The end of the packet will show either:

- A reading showing the internal temperature of the unit. You will see a "DegC" ASCII string as the last four bytes of the packet. The two bytes before this string are the thermistor's reading in C in hex 8.8 format. This is in "big indian format" - i.e. the byte immediately preceding the DegC text is the whole degrees, and the byte preceding that is the fraction of a degree in 1/256 increments. So if you see c0 1a, the temperature of the thermistor is 26.75 degrees C.

- Or, the version number of the firmware in ASCII character format "Vn.n" where n.n is the version number, i.e. "1.5".

The HDL-64E data is presented as distances and intensities only. Velodyne includes a packet viewer called DSR, whose installer files are on the CD that came with the unit. DSR reads in the packets from the HDL-64E unit, performs the necessary calculations to plot the points presented in 3-D space, and plots the points on the viewer screen.

Note: The HDL-64E will output three upper block packets for every one lower block packet. This provides more resolution when identifying objects at greater distances.

The minimum return distance for the HDL-64E is approximately three feet. **Returns closer than this should be ignored.**

Correction Angles

Each HDL-64E laser is fixed with respect to vertical angle and offset to the rotational index data provided in each packet. For each data point issued by the HDL-64E, rotational and horizontal correction factors must be applied to determine the point's location in 3-D space referred to by the return. Each HDL-64E unit comes with its own unique .XML file, called db.XML, that was generated as a result of the calibration performed at Velodyne's factory. DSR uses this XML file to display points accurately. The .XML file also holds the key to interpreting the packet data for users that wish to create their own interpretation and plotting routines.

db.XML contains 64 instances of the following five values used to interpret the packet data:

rotCorrection: This parameter is the rotational correction angle for each laser, as viewed from the back of the unit. Positive factors rotate to the left, and negative values rotate to the right.

vertCorrection: This parameter is the vertical correction angle for each laser, as viewed from the back of the unit. Positive values have the laser pointing up, and negative values have the laser pointing down.

distCorrection: Each laser has its own unique distance due to minor variations in the parts used to construct the laser. This correction factor, in centimeters, accounts for this variance. This number should be directly added to the distance value read in the packet.

vertoffsetCorrection: This value represents the height of each laser as measured from the bottom of the base. It is a fixed value for all upper block lasers and a different fixed value for all lower block lasers.

horizOffsetCorrection: This value represents the horizontal offset of each laser as viewed from the back of the laser. It is a constant positive or negative value for all lasers.

Use the above values from the .XML file to calculate each point's position in 3-D space. Use the first 32 points for the upper block and the second 32 points for the lower block. The rotational info found in the header is used to determine the packets position with respect to the 360 degree horizontal field of view.

Note: There is a file on the CD called "HDL Source Example" that shows the calculations using the above correction factors.

Controlling the Spin Rate

The HDL-64E can spin at rates ranging from 300 RPM (5 Hz) to 900 RPM (15 Hz). The default is 600 RPM (10 Hz). Note that changing the spin rate does not change the data rate – the unit will send out the same number of packets (at a rate of one million data points per second) regardless of spin rate. The image resolution will increase or decrease depending on rotation speed. See Appendix B for angular resolution figures for various spin rates.

To control the HDL's spin rate, connect the serial cable to an available RS-232 COM port and issue a serial command of the format #HDLRPMnnn$ where nnn is an integer between 300 and 900. The characters are case sensitive and must be CAPS. The HDL-64E will adopt the new spin rate. Use the following serial parameters: Baud 9600, Parity: None, Data bits: 8, Stop bits: 1. The HDL-64E has no echo back feature, so no serial data will be returned from the HDL-64E.

FIRMWARE UPDATE

Velodyne may issue firmware updates from time to time. To apply the update, connect the DB9 RS-232 cable to a standard Windows-compatible PC's serial port. The HDL-64E must be powered up and spinning during the update.

Execute the file supplied by Velodyne – all the software and firmware is included to update the unit. Once the file is executed, the following screen will appear:

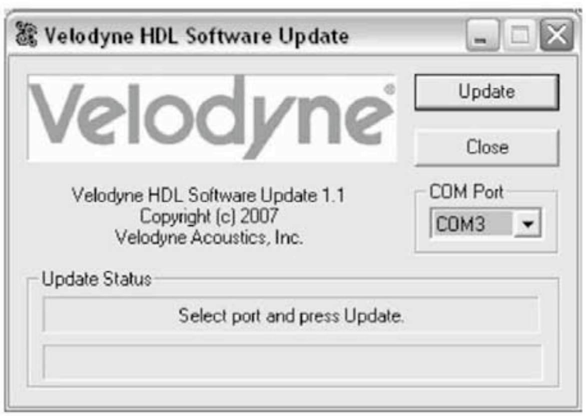


Figure 5. HDL software update screen capture.

Press update and the unit will update. If the update was successful, the unit will begin to spin down for a few seconds then power back up with the new firmware running. If the first update is not successful, it is recommended to try the update again several times before seeking assistance from Velodyne.

NOTE: The entire new firmware is uploaded and checksummed before being applied to the flash memory inside the HDL-64E. If the checksum is corrupted, no software update occurs. This protects the unit in the event of power or data loss during the firmware update.

TROUBLESHOOTING

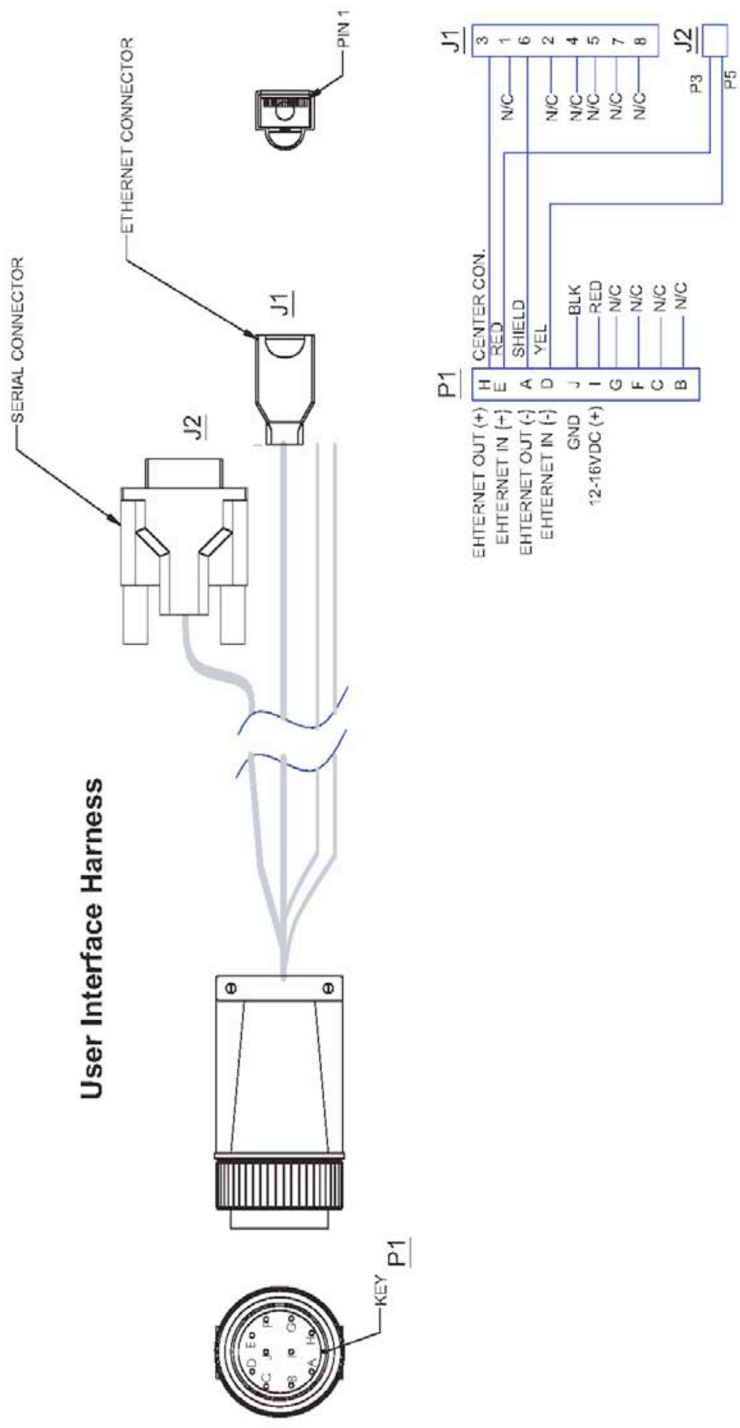
Use this chart to troubleshoot common problems with the HDL-64E.

Problem	Resolution
Unit doesn't spin	Verify power connection and polarity. Verify proper voltage – should be 12 volts drawing about 3-4 amps. Remove bottom cover and check inline fuse. Replace if necessary.
Unit spins but no data	Verify Ethernet wiring. Verify packet output from another source (e.g. Ethereal/Wireshark).
No serial communication	Verify RS-232 cable connection. Unit must be active and spinning for RS-232 update. It may take several tries for the update to be effective.

SPECIFICATIONS

Sensor:	• 64 lasers/detectors • 360 degree field of view (azimuth) • 0.09 degree angular resolution (azimuth) • 26.8 degree vertical field of view (elevation) +2° up to -24.8° down with 64 equally spaced angular subdivisions (approximately 0.4°) • <5 cm distance accuracy • 5-15 Hz rotation rate update (user selectable) • 50 meter range for pavement (~0.10 reflectivity) • 120 meter range for cars and foliage (~0.80 reflectivity) • >1M points per second • <0.05 milliseconds latency
Laser:	• Class Im - eye safe • 4 x 16 laser block assemblies • 905 nm wavelength • 10 nanosecond pulse • Adaptive power system for minimizing saturation and blinding
Mechanical:	• 12V input (16V max) @ 4 amps • <29 lbs. • 10" tall cylinder of 8" OD radius • 300 RPM - 900 RPM spin rate (user selectable)
Output:	• 100 MBPS UDP Ethernet packets

APPENDIX A - CONNECTOR WIRING DIAGRAM



APPENDIX B - ANGULAR RESOLUTION

Lower Block				
RPM	RPS	Points Per Revolution	Points Per Revolution Per Laser	Angular Resolution (degrees)
300	5	50000	1562.5	0.2304
600	10	25000	781.25	0.4608
900	15	16667	521	0.6912

Upper Block					
RPM	RPS	Points Per Revolution	Points Per Revolution Per Laser	Angular Resolution (degrees)	Post-Lower-Block Angular Resolution (degrees)**
300	5	200000	6250	0.0576	0.1152
600	10	100000	3125	0.1152	0.2304
900	15	66667	2083	0.1728	0.3456

Notes:

The HDL-64E generates 1 million points per second

- The lower block reports 250,000 points
- The upper block reports 750,000 points

There are three upper block packets then one lower block packet reported, then the pattern repeats.

** The first upper block measurement after the lower block measurement reports has half the angular resolution.

Appendix C - Digital Sensor Recorder (DSR)

Digital Sensor Recorder (DSR)

The CD that is included with the HDL-64E sensor contains a point cloud visualization program called Digital Sensor Recorder (DSR).

Install DSR on your computer. It is recommended that you accept the default settings, file locations, etc. during this process.

To launch DSR, double click on the DSR icon created on the desktop during the installation. With power applied to the sensor (it will be rotating) and the Ethernet line connected to the computer, you can display the point cloud of data generated by the sensor. Be sure to select the proper Ethernet input device which is the Options window. Confirm in Properties (in Option pull-down) that all laser channels are selected, or just select the channels you wish to view. A mouse click on the Play triangle will result in the display of the current data using the double arrow button. To view a pcap file previously saved, use the Open command in the File pull-down (after the file is loaded, you can begin the playback using the Play button).

You can zoom in and out of the scene by either using the scroll feature on your mouse or the key strokes described below. Perspective can be changed by clicking the mouse and moving the cursor to rotate the image. Be mindful that it is possible to completely invert the image and you may be looking at the image upside down, which can be confusing. During playback, the Pause button (double vertical bars) will pause the image. The Red square represents stop. As with conventional VCR/DVD commands, the double triangles represent forward and reverse motion in the file.

The X, Y, Z and distance figures at the bottom of the image represent the distance of the x,y,z crosshairs with respect to the origin point indicated by the small white circle.

In live display mode, click on the double arrow button to begin display. The concentric gray circles and grid lines represent 10 meter increments from the sensor, which is depicted on the screen by a white circle.

Utilizing the db.XML calibration data file in DSR

The db.XML file provided with your Velodyne HDL-64E contains all of the necessary data for the proper alignment of the point cloud information gathered by the HDL sensor for each laser. {vertical correction (deg), rotational correction (deg), distance correction (cm), vertical offset (cm), horizontal offset (cm), minimum and maximum intensity (0-255)}.

When implemented properly, the image viewable from the Digital Sensor Recorder (DSR) will be properly calibrated to provide an accurate visual representation of the environment in which the sensor is being applied.

This data should also be used in any other program using the data generated by the HDL-64E.

To integrate the db.XML file into the DSR program, follow these steps.

1. Provided that DSR has been installed on the host computer using the default settings, follow this path: c:\program files\Digital Sensor Recorder
2. Cut and paste the existing db.XML file to another location and rename as the default_db.XML
3. Copy and paste the db.XML file provided on the CD to the DSR program folder previously opened
4. Close out the windows and the program is ready to run
5. Open the DSR program
6. Click options\properties
7. Check that the new values are present and that they reflect the values in the example screen captures provided on the CD [Fig.6]
8. Your DSR viewer is now calibrated to your sensor

Properties

Scanner Properties

Distance LSB: 0.20 cm

Scanner Position (cm): X: 0.0 Y: 0.0 Z: 0.0

Scanner Angle (deg): Roll: 0.0 Pitch: 0.1 Yaw: 0.0

Laser Properties

ID	Enabled	Intensity On	Color	Vertical Corr. (deg)	Rotational Corr. (deg)	Distance Corr. (cm)	Vert. Offset Corr. (cm)	Horiz. Offset Corr. (cm)	Min Intensity	Max Intensity
29	☑	☐		2.020810	2.200000	36.000000	0.000000	4.000000	0	255
28	☑	☐		1.679890	0.500000	22.000000	0.000000	-4.000000	0	255
25	☑	☐		1.339140	-1.800000	38.000000	0.000000	4.000000	0	255
24	☑	☐		0.998555	-3.700000	23.000000	0.000000	-4.000000	0	255
3	☑	☐		0.658119	6.200000	43.000000	0.000000	4.000000	0	255
2	☑	☐		0.317822	4.000000	32.000000	0.000000	-4.000000	0	255
31	☑	☐		-0.022350	1.400000	40.000000	0.000000	4.000000	0	255
30	☑	☐		-0.362407	-0.400000	25.000000	0.000000	-4.000000	0	255
27	☑	☐		-0.702363	-2.800000	38.000000	0.000000	4.000000	0	255
26	☑	☐		-1.042230	-4.700000	28.000000	0.000000	-4.000000	0	255
21	☑	☐		-1.382020	6.700000	25.000000	0.000000	4.000000	0	255
20	☑	☐		-1.721740	4.700000	18.000000	0.000000	-4.000000	0	255
17	☑	☐		-2.061410	2.600000	34.000000	0.000000	4.000000	0	255
16	☑	☐		-2.401040	0.800000	29.000000	0.000000	-4.000000	0	255
13	☑	☐		-2.740630	-1.800000	28.000000	0.000000	4.000000	0	255
12	☑	☐		-3.080210	-3.300000	24.000000	0.000000	-4.000000	0	255
23	☑	☐		-3.300000	5.800000	30.000000	0.000000	4.000000	0	255
22	☑	☐		-3.759370	4.000000	17.000000	0.000000	-4.000000	0	255
19	☑	☐		-4.098960	1.500000	32.000000	0.000000	4.000000	0	255
18	☑	☐		-4.438590	-0.400000	22.000000	0.000000	-4.000000	0	255
15	☑	☐		-4.778260	-2.800000	32.000000	0.000000	4.000000	0	255
14	☑	☐		-5.117980	-4.600000	19.000000	0.000000	-4.000000	0	255
9	☑	☐		-5.457770	6.500000	37.000000	0.000000	4.000000	0	255
8	☑	☐		-5.797640	5.000000	20.000000	0.000000	-4.000000	0	255

Selected color:

Figure 6. Calibration values as seen in DSR/File/Properties

DSR Key Controls

Zoom:
Z = Zoom in
Shift, Z = Zoom out

Z axis rotation:
Y = Rotate CW
Shift, Y = Rotate CCW

X axis rotation:
P = Rotate CW
Shift, P = Rotate CCW

Y axis rotation:
R = Rotate CW
Shift, R = Rotate CCW

Z Shift:
F = Forward
B = Back

X Shift:
L = Left
H = Right

Y Shift:
U = Up
D = Down

Aux. Functions:
Ctrl, (Z,Y,P,R,F,B,L,H,U,D) Direction = Fine Movement

Alt, (Z,Y,P,R,F,B,L,H,U,D) Direction= Very Fine Movement

DSR Mouse Controls

Rotational:
Left Button/Move

Slide:
Right Button/Move

Zoom:
Scroll forward = Zoom In
Scroll backward = Zoom Out

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63-HDL-64E Rev C OCT07

APPENDIX B – MANUFACTURER'S LASER DIODE SPECIFICATION

Nanostack Impuls-Laserdiode im Plastikgehäuse 75 W Spitzenleistung
Nanostack Pulsed Laser Diode in Plastic Package 75 W Peak Power

Lead (Pb) Free Product - RoHS Compliant

SPL PL90_3

Besondere Merkmale

- Kostengünstiges Plastikgehäuse
- Zuverlässiges InGaAs/GaAs kompressiv verspanntes Halbleiter-Material
- Hochleistungslaser mit „Large-Optical-Cavity" (LOC) Struktur für ein schmales Fernfeld
- Nanostack Lasertechnologie beinhaltet mehrere epitaktisch integrierte Emitter
- Austrittsöffnung 200 µm × 10 µm

Features

- Low cost plastic package
- Reliable strained InGaAs/GaAs material
- High power large-optical-cavity (LOC) structure for a narrow far-field
- Nanostack laser technology including multiple epitaxially stacked emitters
- Laser aperture 200 µm × 10 µm

Anwendungen

- Entfernungsmessung
- Sicherheit, Überwachung
- Beleuchtung, Zündung
- Test- und Messsysteme

Applications

- Range finding
- Security, surveillance
- Illumination, ignition
- Test and measurement systems

Sicherheitshinweise

Je nach Betriebsart emittieren diese Bauteile hochkonzentrierte, nicht sichtbare Infrarot-Strahlung, die gefährlich für das menschliche Auge sein kann. Produkte, die diese Bauteile enthalten, müssen gemäß den Sicherheitsrichtlinien der IEC-Norm 60825-1 behandelt werden.

Safety Advices

Depending on the mode of operation, these devices emit highly concentrated non visible infrared light which can be hazardous to the human eye. Products which incorporate these devices have to follow the safety precautions given in IEC 60825-1 "Safety of laser products"

Typ **Type**	**Emitteranzahl** **Number of Emitters**	**Opt. Spitzenausgangsleistung** **Opt. Peak Power**	**Wellenlänge** **Wavelength**	**Bestellnummer** **Ordering Code**
SPL PL90_3	3	75 W	905 nm	Q62702P5353

Opto Semiconductors OSRAM

Grenzwerte (kurzzeitiger Betrieb) (T_A = 25 °C)
Maximum Ratings (short time operation)

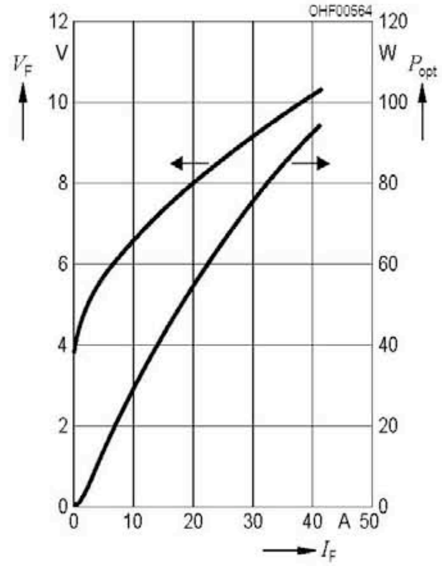
Parameter Parameter	Symbol Symbol	Werte Values		Einheit Unit
		min.	max.	
Spitzenausgangsleistung Peak output power	P_{peak}	–	90	W
Spitzendurchlaßstrom Peak forward current	I_F	–	40	A
Pulsbreite (Halbwertsbreite) Pulse width (FWHM)	t_p	–	100	ns
Tastverhältnis Duty cycle	$d.c.$	–	0.1	%
Sperrspannung Reverse voltage	V_R	–	3	V
Betriebstemperatur Operating temperature	T_{op}	- 40	+ 85	°C
Lagertemperatur Storage temperature	T_{stg}	- 40	+ 100	°C
Löttemperatur (t_{max} = 10 s, 2 mm von Gehäuseunterseite) Soldering temperature (t_{max} = 10 s, 2 mm from bottom edge of case)	T_s	–	+ 260	°C

Optische Kennwerte (T_A = 25 °C)
Optical Characteristics

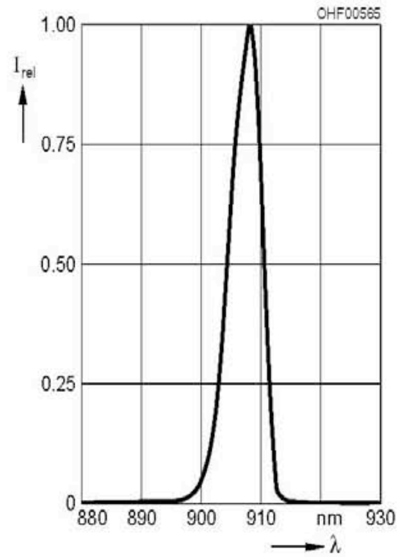
Parameter Parameter	Symbol Symbol	Werte Values			Einheit Unit
		min.	typ.	max.	
Zentrale Emissionswellenlänge[1)] Emission wavelength[1)]	λ_{peak}	895	905	915	nm
Spektralbreite (Halbwertsbreite)[1)] Spectral width (FWHM)[1)]	$\Delta\lambda$	–	7	–	nm
Spitzenausgangsleistung[1)] Peak output power[1)]	P_{op}	65	75	85	W
Schwellstrom Threshold current	I_{th}	0.5	0.75	1.0	A
Betriebsspannung[1)] Operating voltage[1)]	V_{op}	8	9	11	V
Minimale Anstiegs- und Abfallzeit (10% …90%) Minimum rise and fall time (10% … 90%)	t_r, t_f	–	1	–	ns
Austrittsöffnung Aperture size	$w \times h$	–	200 × 10	–	µm
Strahldivergenz (Halbwertsbreite) Beam divergence (FWHM)	$\theta_{\parallel} \times \theta_{\perp}$	–	11° × 25°	–	Grad deg.
Temperaturkoeffizient der Wellenlänge Temperature coefficient of wavelength	$\partial\lambda / \partial T$	–	0.28	–	nm/K
Temperaturkoeffizient der opt. Ausgangsleistung Temperature coefficient of optical power	$\partial P_{op} / P_{op} \partial T$	–	-0.4	–	%/K
Thermischer Widerstand Thermal resistance	$R_{th\ JS}$	–	160	–	K/W

1) Standardbetriebsbedingungen beziehen sich auf eine Pulsbreite von 100 ns bei einer Frequenz von 1 kHz und einem Betriebsstrom von 30 A bei T_A = 25 °C.
Standard operating conditions refer to pulses of 100 ns pulse width at 1 kHz rate with 30 A operating current at T_A = 25 °C.

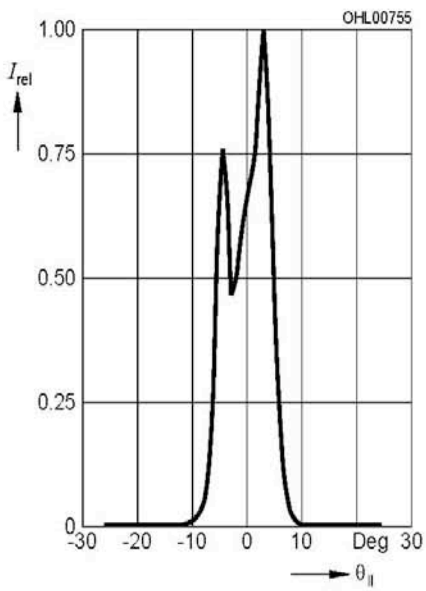
Optical output power P_{opt} and forward voltage V_F vs. forward current I_F (T_A = 25 °C)



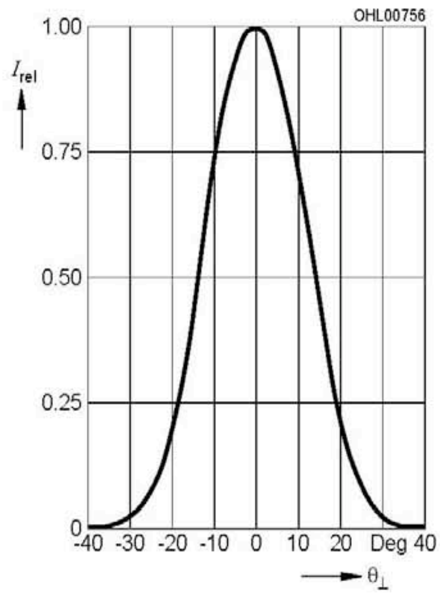
Optical spectrum, relative intensity I_{rel} vs. wavelength λ (T_A = 25 °C, P_{opt} = 75 W)



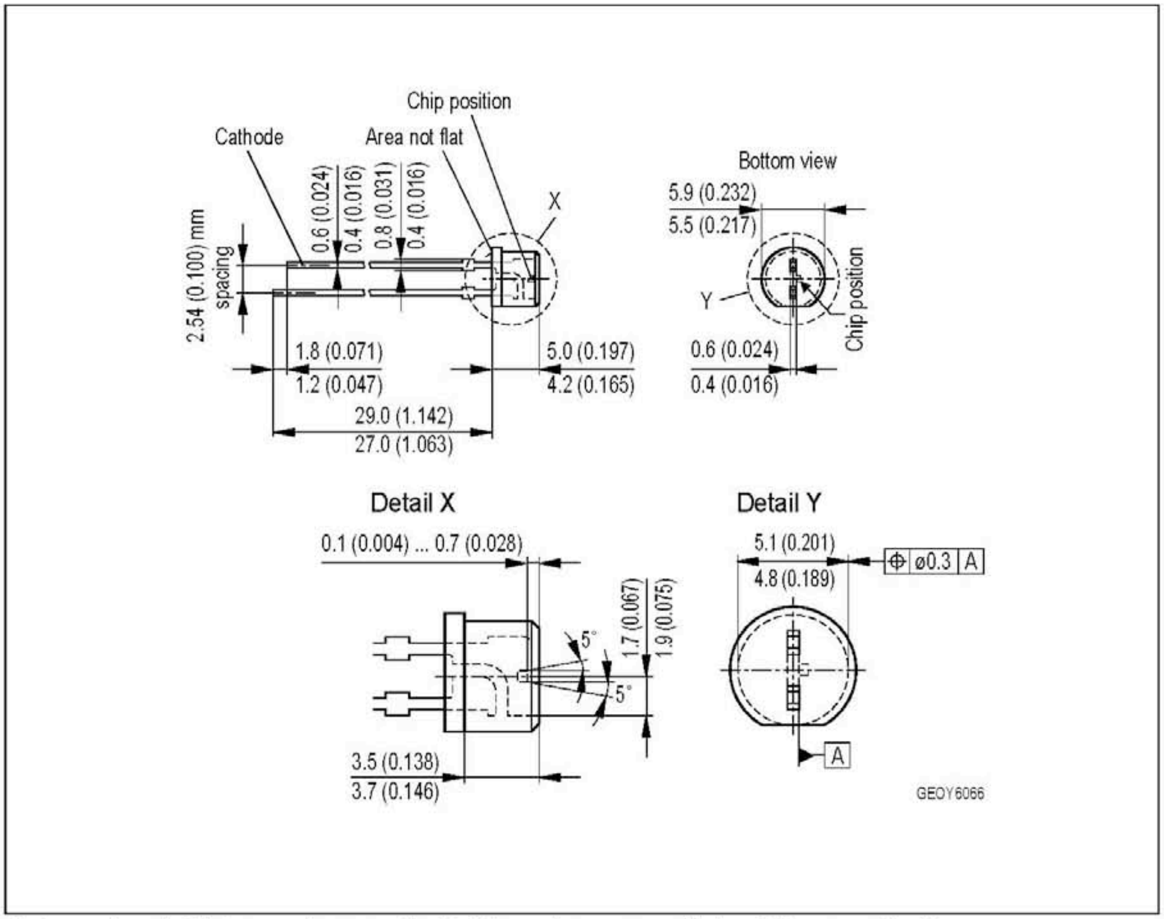
Far-field distribution parallel to junction I_{rel} vs. $\theta_{\parallel}$ (T_A = 25 °C, P_{opt} = 75 W)



Far-field distribution perpendicular to junction I_{rel} vs. $\theta_{\perp}$ (T_A = 25 °C, P_{opt} = 75 W)



Maßzeichnung
Package Outlines



Maße werden wie folgt angegeben: mm (inch) / Dimensions are specified as follows: mm (inch).

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The information describes the type of component and shall not be considered as assured characteristics.
Terms of delivery and rights to change design reserved. Due to technical requirements components may contain dangerous substances. For information on the types in question please contact our Sales Organization.

Packing

Please use the recycling operators known to you. We can also help you – get in touch with your nearest sales office. By agreement we will take packing material back, if it is sorted. You must bear the costs of transport. For packing material that is returned to us unsorted or which we are not obliged to accept, we shall have to invoice you for any costs incurred.

Components used in life-support devices or systems must be expressly authorized for such purpose! Critical components [1] , may only be used in life-support devices or systems [2] with the express written approval of OSRAM OS.

[1] A critical component is a component usedin a life-support device or system whose failure can reasonably be expected to cause the failure of that life-support device or system, or to affect its safety or effectiveness of that device or system.

[2] Life support devices or systems are intended (a) to be implanted in the human body, or (b) to support and/or maintain and sustain human life. If they fail, it is reasonable to assume that the health of the user may be endangered.

APPENDIX C – INSPECTION CHECK LIST

Velodyne	**Title:** Form, Checklist, WIP, HDL	**Doc P/N:** 70-0008	**Rev:** E3

Model #: 80-HDL64E W/O#: ________________ Date:______________

S/N#: ________________

Items:	Serial #:
Upper Detector PCB	______________________
Lower Detector PCB	______________________
UL Laser Assembly	______________________
UR Laser Assembly	______________________
LL Laser Assembly	______________________
LR Laser Assembly	______________________
Upper Block Assembly	______________________
Lower Block Assembly	______________________
DSP PCB	______________________
Motor Assembly	______________________
Outside Shell Assembly	______________________

Change History:

Revision	Description of change	Effective	Change by
E1	Initial Release.	2/12/07	S.Ng
E2	Checklist Updated. Add Task# 240.	3/8/07	S.Ng
E3	Added additional lockdown checks and pack& ship checks.	3/19/07	S.Ng

Task# 230 Document Preparation:

Task# 230	Descriptions	By	Date	Verify
230.1	Verify the following checklists attached with this document. _ Checklist 66-0005 (Upper Detector PCB Alignment) _ Checklist 66-0005 (Lower Detector PCB Alignment) _ Checklist 66-0006 (Upper Block Laser Alignment) _ Checklist 66-0007 (Lower Block Laser Alignment) _ Checklist 66-0002 (Motor Assembly) _ Checklist 66-0003 (DSP Board)			
230.2	Verify all S/N's (except Outer Shell Assy.) are filled in on Page 1 of this document.			

Task# 240 Wiring:

Task# 240	Descriptions	By	Date	Verify
240.1	Verify all the laser cables are connected properly according to the color code diagram P/N: 70-0009.			
230.2	Verify the Upper and Lower Block Flat Flex Cables are copper shielded and connected properly onto the boards.			

Task# 400 Check for 64 Lasers (1st Time):

Task# 400	Descriptions	By	Date	Verify
400.1	Verify all 32 Lasers on upper board are firing.			
400.2	Verify all 32 Lasers on lower board are firing.			

Task# 450 Preliminary Balance

Task# 450	Descriptions	By	Date	Verify
450.1	Verify the unit without the shell is balanced. Reading from Oscilloscope: Channel 1: ____________mV (9.0 mV max) Channel 2: ____________mV (9.0 mV max)			

Task# 480 1st Images Check

Task# 480	Descriptions	By	Date	Verify
480.1	Bring the Unit outside and check for Images			

Task# 500 Balance with Shell

Task# 500	Descriptions	By	Date	Verify
500.1	Verify the unit with shell is balanced with additional weight on the **outside** of the shell. Reading from Oscilloscope: Channel 1: ____________mV (6.0 mV max) Channel 2: ____________mV (6.0 mV max)			
500.2	Verify the unit with shell is balanced with additional weight on the **inside** of the shell. Reading from Oscilloscope: Channel 1: ____________mV (7.0 mV max) Channel 2: ____________mV (7.0 mV max)			

Task# 520 Check for 64 Lasers (2nd Time):

Task# 520	Descriptions	By	Date	Verify
520.1	Verify all 32 Lasers on upper board are firing.			
520.2	Verify all 32 Lasers on lower board are firing.			

Task# 550 Hardware Lock Down

Task# 550	Descriptions	By	Date	Verify
550.1	Apply Loctite 242 (Blue) to all setscrews on the moveable counter weights on the round rods.			
550.2	Apply Loctite 242 (Blue) to the both 10-32 screws on the round counter weights on the upper block.			
550.3	Verify all screws inside the unit are tightened.			
550.4	Verify all cables inside the unit are security tied down.			
550.5	Verify all lens are clean and without any scratches.			
550.6	Verify the window on the shell is clean.			
550.7	Remove Jumper J34 on DSP board.			
550.8	Verify all S/N’s on Page 1 of Checklist 66-0001 is filled.			
550.9	Install O-Ring (P/N: 48-116) on the bottom of the Shell Mount Base Plate.			
550.9	Install the shell and apply Loctite 242 (Blue) to Shell screws with lock washers.			
550.10	Flip the unit upside down. Verify there is no loose object inside the unit.			
550.11	Install the Square Base Assembly to the unit.			

550.13	Verify the use of the following hardware to mount the Rotary Coupling Connector Assy. (P/N: 82-507) to the bottom of the motor spindle: Qty 3: 4-40 x 3/8" Soc Cap screws P/N: 40-043SHCS With Loctite 242 (Blue) Qty 3: #4 Lock washer. P/N:43-04SL Qty 3: #4 Flat washer (Special) P/N: 43-04			

Task# 570 Check for 64 Lasers (3rd Time):

Task# 570	Descriptions	By	Date	Verify
570.1	Verify all 32 Lasers on upper board are firing.			
570.2	Verify all 32 Lasers on lower board are firing.			

590 Images Check (2nd Time)

Task# 590	Descriptions	By	Date	Verify
590.1	Install the bottom square cover with O-ring.			
590.2	Bring the Unit outside and check for Images.			

Task# 600 Burn-In

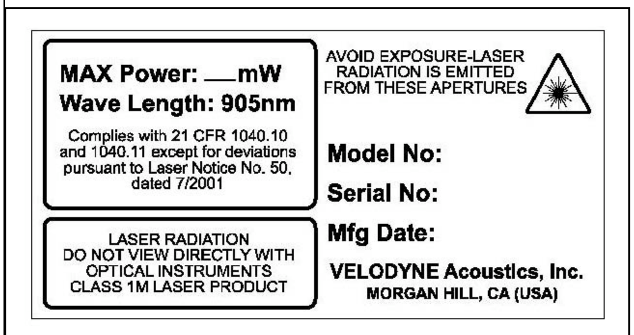
Task# 600	Descriptions	By	Date	Verify
600.1	Record Start Time and End Time Start Date : ____________ Time: ______________ End Date: _____________ Time: ______________ Total Burn-In Time: ______________________hrs			

Task# 800 Final Images Check

Task# 800	Descriptions	By	Date	Verify
800.1	Install the bottom square cover with O-ring.			
800.2	Bring the unit outside and check for images.			

Task# 990 Pack and Ship

Task# 990	Descriptions	By	Date	Verify
990.1	Verify Velodyne S/N label installed on the bottom of the unit.			
990.2	Tool Kit P/N: 92-0090 Verify all the item are inside the tool pouch: Qty:1 ___ Tool Pouch P/N: 92-0101 ________________________ **Hex Allen Wrench Drivers:** Qty:1 ___ 050" Hex Allen Wrench P/N: 92-0091 Qty:1 ___ 1/16" Hex Allen Wrench P/N: 92-0092 Qty:1 ___3/32" Hex Allen Wrench P/N: 92-0095 Qty:1 ___ 5/64" Hex Allen Wrench P/N: 92-0097 **Hex Allen Wrench/T Handle:** Qty:1 ___3/16" Hex Allen Wrench w/T-Handle P/N: 92-0093 Qty:1 ___3/32" Hex Allen Wrench w/T-Handle P/N: 92-0094 Qty:1 ___7/64" Hex Allen Wrench w/T-Handle P/N: 92-0098 Qty:1 ___9/64" Hex Allen Wrench w/T-Handle P/N: 92-0099 Qty:1 ___5/32" Hex Allen Wrench w/T-Handle P/N: 92-0096 **Hex Socket Wrench:** Qty:1 ___7/64" Hex Socket Wrench **Tweezer:** Qty:1 ___Tweezer, #2A Taper Round Blunt 4 _" Lg SS P/N: 92-0101			

	Qty:1 ___Lens Cleaning Paper Sheets Pack P/N: 92-0102 **Labels:** Qty:1 ___ Label, Class 1 M Laser Warning Verify Model #, Serial # and Mfg Date are written on the label using the black permanent marker pan. P/N:63-131  Qty:4 ___ Label, Warning, Triangle P/N: 63-132			
990.3	Verify tool kit pouch and connection cables are put inside the crate.			
990.4	Verify this Checklist is completed.			

Rework History (1st Page)

Date	Reject Description	Rejected By	Comments
Date	Failure Analysis	Performed By	Comments
Date	Description of Rework	Reworked By	Comments
Date	Reject Description	Rejected By	Comments
Date	Failure Analysis	Performed By	Comments
Date	Description of Rework	Reworked By	Comments

Rework History (2^{nd} Pages)

Date	Reject Description	Rejected By	Comments
Date	Failure Analysis	Performed By	Comments
Date	Description of Rework	Reworked By	Comments
Date	Reject Description	Rejected By	Comments
Date	Failure Analysis	Performed By	Comments
Date	Description of Rework	Reworked By	Comments

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